PSYCHOLOGY

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PSYCHOLOGY

G-V

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PREFACE

Modern psychology is the gradually evolved product of the researches and hypotheses of several generations of scientists. Introducing a beginning student to this broad field is a serious task, the aims and means of which should be scrutinized carefully. Three principal objectives of the introductory course in psychology may be suggested. First, the student must be imbued with the experimental and critical spirit of psychology. He must become convinced that human problems can be regarded dispassionately and investigated objectively, so that the conclusions obtained transcend those of controversy and opinion. The student may forget many of the details of psychology, and undoubtedly will; but if he has caught the experimental attitude of the science, he will have formed a significant link in his liberal education.

A second objective of an introductory course in psychology is to acquaint the student with representative samples of the results of psychological research, and with the most acceptable interpretations of these findings. Almost all unprejudiced thinkers agree that psychology has a large body of subject matter of an uncontroversial nature that is of value for its own sake. This experimental content should be presented clearly, fairly, and interestingly to the beginner, and without factional bias. In the introductory course all hobbies should be stabled and all hatchets buried.

As a third aim, it is proper that the introductory course should describe some applications of psychology to the present needs of students, and to the problems that they may face in the future. The student must feel that psychology is the study

of himself and of other real human beings, and not of an artificial creature set up in the laboratory.

Each of the three aims of introductory psychology must be achieved in moderation and with due regard for substantial integration with the others. In the past there have been introductory textbooks that were tedious with method and others that were bulky with subject matter. The laudable recent trend toward interesting and practical applications can also be one-sided, if it is followed to the exclusion of the spirit and substance of the science. The authors do not suppose that this textbook has attained the three stated objectives with perfect effectiveness, but these aims have guided them in its preparation. Their purpose has been to make a balanced presentation of psychological attitudes, researches, and practical applications, within the limited scope imposed by the introductory course.

Some other governing principles have also directed the preparation of this work. The whole, integrated human being has been ever before us, and has been incorporated in the beginning of the text, at the end, and at every point between. The genetic approach has been employed extensively. All the principal trends of human action are traced from their beginnings and are described as growing and changing processes. In keeping with a genetic point of view, experiments with infra-human animals are cited whenever they seem likely to contribute to an understanding of human behavior. The social aspects of psychology, the reciprocal relationships between the individual and his cultural group, are prominent in the authors' conception of the book. This social material is not segregated, but is combined with its proper contexts throughout.

The book is organized in a progressive sequence, in which the subject matter of each chapter has a meaningful relationship with what has preceded it. The authors hope that this organization will counteract psychological atomism, and will emphasize the correlations among the various topics. Since meaningful relationships favor understanding and remember-

ing, a related sequence has undoubted advantages to the student. For those who wish to think of the book as organized into units larger than a chapter, five main groupings may be distinguished. The first three chapters are introductory and give the student his first acquaintance with psychology's approach to the study of man. Chapters IV to VII trace the development of behavior genetically from prenatal to mature levels, and from simple activities to the most complex of which man is capable. The emphasis of these chapters is on motor behavior, which offers a lucid and significant first approach. In Chapters VIII to XI, the student encounters the problems of conscious experience, introduced by a genetic survey and continued through the principal sensory modes. It is obvious that man is a conscious organism, and the authors believe that his awareness is just as important as his muscular behavior. Chapters XII and XIII, on remembering and thinking, bring together human activities that can be understood fully in the light of both the preceding behavioral and experiential approaches. The concluding chapters, XIV to XVI, continue the theme of the whole man in relation to his abilities, character, personality, and social adjustments.

Certain features of the book are designed to facilitate its use by students. Suggested references, with emphasis on a practicable shelf of books for supplementary reading, are given in the back of the volume. A glossary of technical terms is included in the index. In addition, several types of supplementary materials have been prepared as separate units. In comparison to the other natural sciences, psychology often suffers from a lack of definite activities to carry on while studying. The use of the supplementary materials may help to combat the students' tendency merely to read the text. Preliminary editions of the textbook and of some of the other materials have been tried in classes for a period of two years.

The authors' greatest debt of gratitude is to the many psychologists who by their researches, their theories, and their critical contributions have built the substance of the science.

The work of these psychologists has been drawn upon freely and often without specific acknowledgment, as is inevitable in an introductory treatise. Our colleagues, Robert G. Simpson and James M. Porter, Jr., have used the preliminary edition of the book in teaching, and have been most helpful with advice and criticism. The authors wish to express their great appreciation of the assistance rendered by Professors Arthur G. Bills of the University of Cincinnati, Norman Cameron of the University of Wisconsin, Edmund S. Conklin of Indiana University, John P. Foley, Jr., of George Washington University, Harry W. Hepner of Syracuse University, Harry W. Karn of the University of Pittsburgh, Don Lewis of the University of Iowa, Arthur W. Melton of the University of Missouri, Presley D. Stout of New York University, and William R. Wilson of the University of Washington. These psychologists read the book before its publication, made a number of corrections of detail, and offered many suggestions for its improvement.

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B. v. H. G.
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Pittsburgh,
March, 1940

PSYCHOLOGY

Chapter I

THE AIM AND SCOPE OF PSYCHOLOGY

Why Psychology Is Needed

All living organisms are active, and all are constantly modifying their activities in response to conditions both within their own bodies and in the surroundings in which they live. In fact, an animal must always be ready to alter its behavior to meet new circumstances, or it cannot survive in a constantly changing world. These varied adjustments are not made meaninglessly or at random, but are governed by laws or principles that science can discover. Psychology is the science that studies the activities of living organisms in relation to their environments.

Man is an animal organism. Like all other living bodies, he is acted upon by internal and external forces, and in turn reacts upon his surroundings so as to modify them. To make these adaptations between himself and his environment, man acts, discriminates, senses, understands, reasons, and imagines. Furthermore, his ability to do these things changes from time to time, especially as he develops from a child into an adult. Man adjusts to his environment by his behavior, or what he does, and by his experience, or what he senses and knows. Moreover, unlike the lower animals, man is also interested in studying himself, and in trying to understand his own actions and the influences that determine them. Human psychology serves this last interest, for it endeavors to collect reliable information about the nature, sources, and development of human behavior and experience.

Common Observations of Human Behavior. The question may be raised as to why a special science of human psychology

is necessary or even desirable, since human beings have always been observing themselves and their fellow men. From this accumulation of experiences many formulations have been made about human behavior, abilities and character. The generalizations that arise from everyday common observations are not always valid, however. Along with the truths about human nature that most people know from common observation there exist a great number of errors, a fact of which the student can convince himself by testing his own knowledge of human affairs by means of the following thirty statements. Let him examine these statements, some of which are true and some false, and make a record of those which he holds to be true.[1]

1. Children can learn more quickly and easily than adults.
2. Infants have a large variety of emotions from the time of their birth.
3. The brains of rats and of men have the same principal parts.
4. The memory can be improved by practice.
5. A moron is a person of perverted character.
6. Boys and men have greater intellectual ability than girls and women.
7. Infants do not learn much until they are about one year old.
8. Feeble-minded children have dull eyes and low foreheads.
9. A "thought" is one of the quickest things in the world, occurring almost instantaneously.
10. About ten times as many men as women are color-blind.
11. A person is born with either a good character or a bad character.
12. A strong will power enables a man to do things that he does not want to do.
13. The study of Latin trains the mind to reason clearly.
14. People's beliefs are based chiefly on observation and logical evidence.
15. After learning a lesson, a person forgets more of it in the first few hours than during several following days.
16. Intellectually brilliant children tend to be more nervous than average children.

[1] The student may list the numbers 1 to 30 on a sheet of paper, and write "True" or "False" after each number according to his judgment of the correspondingly numbered statement. The correct answers are given in a note at the end of the chapter.

17. About 90 per cent of Negroes are inferior to white people in intelligence.
18. Lessons learned just before going to sleep are retained better than those learned in the morning.
19. Thinking is done in the upper front part of the brain.
20. Genius is closely related to insanity.
21. Nervousness is caused by weak nerves.
22. Boys who do poorly in academic work have better mechanical ability than do bright boys.
23. Products of the imagination are inferior to those of the reason.
24. Will power is developed by performing difficult and unpleasant tasks.
25. Bright children are physically weaker than the average child.
26. A hypnotist has a peculiar personal power or gift to hypnotize people.
27. A dull child is likely to become more normal as he grows older.
28. Many people are instinctively afraid of the dark.
29. Memories are stored away in the unconscious mind to be remembered later.
30. The Nordic peoples have higher average intelligence than the Mediterranean peoples.

A comparison of the popular and psychological judgments of these statements leads to the conclusion that common observation is not a sufficient guide to a reliable knowledge of human affairs. Moreover, some of the errors that enter into the formation of popular opinion can be identified.

Why Common Observation Is Unreliable. The knowledge of human nature derived from ordinary experience, so often glorified as "common sense," is seriously unreliable in two important respects. First, it is based on superficial and uncontrolled observations, and second, it is colored by preconceptions and prejudices.

In spite of their vast quantity, the everyday observations that people make of their fellow men are of little scientific value because of certain errors that have themselves been subjected to psychological investigation. For instance, experiments show that no one can look at a picture or a store window, and then give an accurate account of what he has seen. Many significant items are unobserved and unremembered, and,

what is even worse, the common observer will usually report the presence of some items that were not actually present. If this is the case for so static an object as a picture or a store window, how much more unreliable is the common observation of complex and rapidly changing human activities! So, in observing his fellows, man often fails to see what he is looking at, and to hear just what he is listening to.

Furthermore, common observations are usually made without a full knowledge of the causes that have operated to bring about the observed result. If two circumstances arise in succession, an ordinary observer is likely to conclude that one has caused the other, whereas the two may be unrelated, or both may be due to some other unobserved cause. Very rarely are observations repeated with sufficient care to test and verify the results. A related source of error is that most people generalize on too little evidence. A striking and exceptional instance, the causes of which may have been observed poorly, is taken to represent the rule, while a thousand unspectacular cases to the contrary may be ignored or forgotten. For example, one apparently successful prediction will make a person believe in fortune tellers, despite many other failures. In this way, popular thought "proves" its points by citing isolated instances without noticing the causes that have made these cases exceptional.

The most serious flaw in the popular understanding of human nature arises from preconception and prejudice. Much human thinking is "wishful thinking." A person tends to believe what he would *like* to believe, rather than what he *can* believe according to the evidences. Conclusions that are flattering or gratifying, or that excuse shortcomings, are accepted too readily. Thus, it is easy for the parent of a stupid child to believe that most great men did not do well in school (which is not true), because he wants to believe so. A man will accept whole-heartedly evidence of very little objective value if it points to the superiority of his race, his nation, his political party, or his children. Conversely, he has a peculiar blindness

for any facts that might be taken as derogatory to his own interests. Since common observations and beliefs are so unreliable, there is a need for a more exact approach to an understanding of human behavior.

What Psychology Is

The Scientific Approach. In contrast to the popular attitude, the psychological approach is a systematic attempt to make exact and unbiased observations of human and animal behavior. Like all other sciences, psychology obtains most of its facts from *experiments*. An experiment is a particular sort of observation. Careful preparation is made in advance to limit the problem to be investigated and to control the conditions that might influence the results. Then one set of circumstances is varied systematically, and a record is kept of the concurrent changes in behavior. Most psychological conclusions are based on experiments performed in laboratories, for only under laboratory conditions can the causes be defined with precision, the results observed or measured exactly, and the procedure defined in such a way as to permit the repetition and verification of the conclusions by other experimenters. Scientific knowledge thus can be demonstrated by evidences that are available to all who have the equipment, training, and interest to look for them. By these means, psychological knowledge is made more precise than common observation.

A second important characteristic of scientific inquiry is the attitude with which it is carried on. The psychological approach to human nature is impartial and objective. A scientist does not try to prove his preconceptions, but is willing to be led by the evidence that he discovers. Psychologists are skeptical of popular beliefs about human nature unless they are verified by objective evidences. The scientist thereby frees himself from the second great fault of common opinion by renouncing prejudice and basing his conclusions on the precise observations made.

Psychology Among the Sciences. Every science has relationships with other sciences. Psychology, since its subject matter

deals with living organisms, is a member of the general science of biology. Within biology, a number of subdivisions are distinguished. Every living organism is a biological machine, and every machine *is* something and *does* something. An animal is a structure of many parts, and its structure functions or works in a certain way. Consequently, two of the biological sciences are *anatomy*, or the science of organic structure, and *physiology*, or the science of organic functions.

Since psychology is concerned with the actions of animals, it might be taken for a part of physiology. But physiology has traditionally concerned itself with the operation of organs or parts, or of limited systems of organs such as the circulatory or digestive systems. The analysis of the structure and the part-operation of animals is not a full account of the significant aspects of life, however. An animal learns, loves, hates, fights, nourishes and protects its young, remembers, forgets, does one thing under one set of conditions and something else under other conditions. These elaborate forms of behavior cannot be ascribed to the operation of any organs or systems of organs separately, but must be described in terms of the integrated activity of the organism as a whole. The individual constantly responds to the environmental forces that play upon him, and it is upon his adjustment to these forces that his survival depends. Psychology takes for its special province the study of the activities of a living body that represent its total functioning in relation to its environment. Psychology is therefore the third member of the triumvirate of biology, which together aim to give a well-rounded picture of what the living organism is and does.

Pure and Applied Science. Some distinction must be made between a science and its applications. As a science, psychology is interested only in an exact description of human and animal behavior, and of the relationships between behavior and the factors that influence it. But this knowledge, which is obtained primarily for its own sake, has important applications in the practical guidance of human affairs. Since psychology studies

human development and learning, it may be applied to the guidance of children and the selection of effective educational methods. These applications are *child psychology* and *educational psychology*. Persons whose life adjustments are seriously disturbed may be studied psychologically; this is the field of *abnormal psychology*. *Social psychology* investigates the behavior of persons in groups and in relation to social institutions. The broad field of *industrial psychology* includes the problems of the selection and training of workers, incentives, fatigue, and safety. All these applications are made by using the findings of general psychology, or by applying psychological research methods to find the answers to special problems. All require the broad foundation provided by pure psychology as a science.

Misrepresentations of Psychology. Since the subject matter of psychology is man, it inevitably arouses popular interest and has widespread appeal. Man wants to know about himself and to improve himself, or at least he likes to believe that he is learning and improving. One unfortunate result of this popular interest has been the advent of pseudo-psychologists who seek to sell the public what it wants, regardless of the worth of the goods offered. Unlike medicine, psychology is not protected by law. A man cannot call himself a physician unless he is qualified; but in most states anyone can style himself a "psychologist," no matter how ignorant or self-seeking he may be.

Because of the prominence of some self-advertising quack "psychologies," it is necessary to make a few statements about what psychology is *not*. Psychology has nothing to do with fortune-telling. It is not possible to tell a person's character or future by examining his features, his hands, the bumps on his head, or his handwriting. All these methods have been subjected to scientific inquiry and shown to be of little or no value. They continue to be practiced, for a fee, only because a gullible public *wants* to believe that the future can be foretold. Neither does psychology substantiate the claims made for telepathy, mind-reading, clairvoyance, or spiritistic manifestations.

A common and incorrect use of the term "psychology"

should be avoided. Often a salesman who has successfully persuaded a customer says that he has "used psychology" on him, or a parent asserts that he "uses psychology" to make a child obey. These usages are essentially unsound. A man who shoots a gun does not "use physics," although his firearm obeys the laws stated in that science. He uses physics only if he calculates the trajectory of the bullet, or computes the force with which it will strike. Similarly, the salesman properly can say that he uses psychology only if he experiments carefully with various approaches to customers, measures the results, and defines precisely the factors leading to success. Dealing with human beings is not "psychology" unless it is done in the experimental spirit, and this is rarely achieved by salesmen, parents, teachers, and other laymen.

One of the most common frauds practiced in the name of psychology preys upon the human desire for self-improvement. Large fees are charged by persons who promise to improve one's personality, to increase the ability to remember, or to double one's income, all in a brief course of easy lessons. This type of quackery is particularly subtle because moderate gains in personal efficiency really can be achieved by hard effort under proper professional guidance. The fraudulent promotors deceive by promising too much, and by making a difficult achievement appear to be within easy reach. They do a little good to a few individuals who need only self-confidence and assurance. But they do much more harm by raising the hopes of other persons who are bitterly disappointed and are also relieved of considerable money during the process. A sound knowledge of scientific psychology provides the best basis for detecting and avoiding the misrepresentations and exploitations of the subject.

How Psychologists Work

The methods that psychologists use to unravel the complexities of human nature can be explained most clearly from specific illustrations of their work. Four of the thirty statements

made earlier in the chapter will serve as examples. In each instance, the experimental findings of psychology give an answer different from that held by the superficial and often prejudiced conclusions of popular opinion.

Can Memory Be Improved by Practice? Many experiments have been performed on the problem of "memory improvement" since the first study was reported by William James in 1890. In general, the experimental method first measures the memorizing ability of a group of persons, then has them practice memorizing other material, and finally tests for a second time their ability to memorize in order to measure any change that may have occurred. If practice has improved the ability to memorize, then the second test should show a gain over the first one. A satisfactory illustration of an experiment on this problem is that of Sleight (1911).[2] Eighty-four British school girls, whose average age was twelve and a half years, were divided into several groups, two of which will be discussed here. One group took tests of their ability to memorize several kinds of material, and then spent one-half hour a day for twelve successive days practicing the memorizing of poetry. At the end of this time the tests were repeated. Another group, the very important *control group*, took the initial and final tests, but were given no practice in memorizing. The memorizing and control groups were *equated*, or made alike in every significant way, such as in age, in other studies pursued at the time, and especially in initial memorizing ability. Conclusions were drawn by comparing the final tests of the two groups, who were alike in every way except for the practice periods in memorizing. This procedure guaranteed that the results would be pertinent to the problem under investigation, and not due to other causes.

Sleight found that his practice group excelled the control group in some of the final tests, but actually fell below it in some others. Thus, the children who had practiced memorizing

[2] References to all research studies and books cited in the text will be found at the end of the volume.

poetry gained considerably in the ability to learn other selections of poetry, and also made smaller gains in the ability to learn nonsense syllables, lists of dates, and verbatim prose passages. But these children were *less able* to learn the substance of prose selections, or lists of letters, than were the children who had done no practicing. Sleight concludes that there is no general memory improvement as a result of practice, since each kind of practice may aid some types of memorizing and may interfere with others. This conclusion has been confirmed by many other experiments, some of which will be described in a later chapter.

If practicing does not really improve "the memory," why does popular opinion accept this belief so readily? The error arises from many sources, some of which can be detected. One cause lies in an uncritical use of analogy. A muscle is strengthened by exercise, and so popular opinion concludes that "the memory" must also be strengthened by practice. This belief ignores the fact that muscles are organs that are very different from the nervous system upon which memorizing depends, and may well obey different laws of functioning. Another source of error is mistaking the result for the cause. Popular observation notes that an educated man learns more readily than an uneducated man, and hence infers that his education has improved his learning ability. But this does not necessarily follow. Instead, the man may have been a good learner at the outset, so that his education may be the *result* of his ease of learning rather than its cause.

Are Bright Children Physically Weaker Than Average Children? This question has been answered in the negative by several statistical studies. For example, Terman (1926) has reported careful physical measurements of a large group of intellectually gifted children, which were compared to those of average children. First, it was necessary to obtain a large and well-chosen sample of mentally bright children. These were selected by individual intelligence tests, an objective procedure that rules out many unreliable factors of personal opinion as

to what constitutes a gifted child. Physical measurements were made of 312 gifted boys and 282 gifted girls whose intelligence quotients (I.Q.) ranged from 130 to 189, as compared to the average I.Q. of 100 for ordinary children. At all ages, the average height and the average weight of the intellectually bright children excelled those of unselected children from similar homes. To cite the exact measurements for one age, the eleven-year-old gifted boys averaged 56.2 inches in height, as compared to an average of 55.2 inches for the non-gifted group. The average weights were 82.2 pounds and 76.0 pounds for the gifted and non-gifted eleven-year-olds, respectively. Furthermore, the intellectually bright children excelled also in arm span, width of shoulders, strength of grip, and many other characteristics. From these carefully measured results, it is evident that bright children as a group are not weak and undersized, but on the contrary are relatively tall, heavy, and strong. Of course, these are average results. Some gifted children are puny, but they are exceptional rather than typical.

If these are the facts, why is popular opinion so strong in picturing the "genius" as a dwarfed and anemic youngster? Superficial observation is again partly at fault. A teacher says, "Why that can't be so! I *know* that the brightest children in my grade are always the little ones." This may be quite true. But the brightest child in a school grade is usually a year or two younger than his classmates. Of course, a bright ten-year-old is likely to be smaller than his twelve-year-old fellows in the sixth grade. It is only when the bright child is compared to average children *of equal age* that the truth is discovered. So simple a fact as age is likely to be ignored by the superficial observations made in everyday life. Prejudice also enters into the formation of popular opinion in this matter. The parent of an average child is eager to find reasons for defending his offspring. If he sees one single gifted child who is puny, he may jump to a conclusion in keeping with his desires, and say, "I'm glad that my son is a strong, healthy, normal child. I wouldn't

want him to be bright, sickly, and weak." Thus a person's wishes are likely to run away with his reasoning.

Do Infants Have a Large Number of Specific Emotions? To answer an important aspect of this question, Sherman (1927) made motion pictures of infants that had just been stimulated by restraint of movement, sudden loss of support, a needle prick, or hunger. Groups of adult judges were shown the motion pictures and were asked to name the emotion displayed and to designate the stimulation that caused it. When only the infants' responses were shown in the pictures, the judgments were scattered and incorrect. For example, with one group of judges the response caused by hunger was called "anger" by 13 observers, "fear" by 7, "hunger" by 7, "pain" by 3, "grief" by one, and "consternation" by one. Other films were judged with no greater accuracy. But if the judges could see the situation that aroused the emotion the accuracy apparently rose, as is indicated by the fact that in the film showing an infant being dropped, 27 of one group of judges called the response "fear" and only 4 called it "anger." The last-mentioned part of the experiment reveals the source of popular error. Adults read into an infant's response their own interpretation of the situation. Since they know that fear is an appropriate response to falling, they ascribe this emotion to the infant. But the infants' responses alone are really indistinguishable, as the earlier part of the experiment shows. In general, many erroneous beliefs about child behavior arise because adults interpret behavior instead of observing it accurately.

How Quick Is a "Thought"? "Quick as a thought" may be very rapid, but it is not as fast as most people are prone to believe. This problem has been investigated by what are called *reaction time* experiments, which are among the oldest in the history of psychology. The reaction time experiment provides a suitable example of the type of study in which complex and precise apparatus must be used. Many psychological experiments require elaborate and carefully controlled equipment,

although this factor has not been shown in the three preceding illustrations.

Reaction times are measured by a mechanical or electrical clockwork instrument known as a *chronoscope*, which measures time in hundredths or thousandths of a second. In a complete reaction time apparatus, the chronoscope is made to start when some signal or stimulus is given, and to stop when the required response has been made by the person being experimented upon (Fig. 1). When a simple reaction time is being measured, the chronoscope starts when a lamp lights and stops when the subject, upon seeing the light, lifts his finger from a telegraph key. A simple visual reaction of this sort requires about .18 of a second, on the average. Even so elementary a "thought" as lifting one's finger upon seeing a signal therefore requires almost one-fifth of a second, a finite and appreciable period of time. The reaction time varies somewhat with the sense organ stimulated. Average values of about .14 of a second are found for reactions to a sound or a touch, which are quicker than those to a visual stimulus.

It may be objected that simple reaction time measures the speed of a muscular movement rather than of a "thought" in the ordinary sense. Experiments show, however, that the introduction of any elements of "thinking" increases the reaction time greatly. If the subject is instructed to react when a red lamp lights, but not to respond to a green light, the reaction time may increase to about .30 of a second. If, further, he is called upon to lift his right hand for a red light, and his left for a green one, the reaction time is increased to an average of about .40 of a second. The muscular response takes no longer for these than for the simple reactions, but the "thinking" takes longer. If the subject is required to name the opposites of easy words such as "black," "tall," or "rich," his response is likely to take one full second, on the average.

The reaction time experiments are useful chiefly in "pure" psychology, but they have some interesting practical applications. Many situations in modern life require rapid responses,

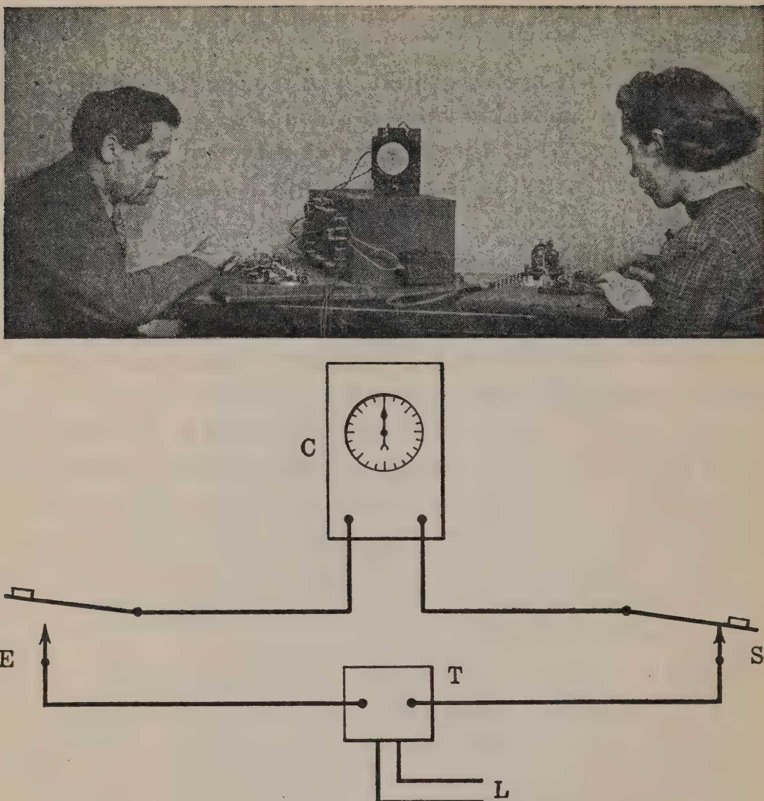


FIG. 1. Apparatus for the Reaction Time Experiment.

At the top is a photograph of a reaction time apparatus. The experimenter sits at the left. In front of him is the experimenter's unit of the apparatus containing the keys, switches and relays to give and control various signals or stimuli. On the top of the experimenter's unit is the impulse counter or chronoscope which measures small intervals of time. The subject sits at the right. The subject's unit contains lights and a sounder for giving various signals, and telegraph keys for making the responses. The experimenter's and subject's units are connected by a long cable and can be placed in separate rooms.

Below is shown a simplified circuit of the reaction time apparatus. When the experimenter presses his key *E* the current from the transformer *T*, connected with the 110-volt 60-cycle line *L*, flows through the impulse counter or chronoscope *C*. The experimenter's key also causes the signal of a sound or a light to be given, through circuits not shown. Upon receiving the signal the subject lifts his hand from the key *S*, and breaks the circuit. This stops the chronoscope, which then indicates the reaction time.

such as the operation of industrial machinery and the driving of automobiles. At a speed of 50 miles per hour an automobile will travel 37 feet in half a second, which is about the minimum reaction time to a complex situation involving danger. This space is traversed in the time it takes the human mechanism to get started, aside from the time taken by the mechanical parts of the automobile.

An Orientation

Psychology is the science that seeks dependable knowledge about the behavior and experiences of human beings and of other animal organisms. Psychology is needed because common opinion about human affairs is unreliable, being based on inadequate observation and distorted by prejudices and preconceptions. Psychology approaches its subject matter in the impartial manner of science, and is guided by the facts that can be discovered by controlled and verifiable methods of observation. Its knowledge, like that of other sciences, is a series of conclusions or inferences from observed data. Psychology does not promise self-improvement, but does offer a better understanding of how human beings and other animal organisms go about their life activities.

The answers to the questions that begin on page 2 are as follows:

1. False (see p. 400)
2. False (see pp. 12, 139)
3. True (see p. 45)
4. False (see pp. 9, 340)
5. False (see p. 401)
6. False (see p. 415)
7. False (see p. 97)
8. False (see p. 401)
9. False (see p. 12)
10. True (see p. 241)
11. False (see p. 445)
12. False (see p. 189)
13. False (see p. 340)
14. False (see p. 438)
15. True (see p. 335)
16. False (see p. 404)
17. False (see p. 416)
18. True (see p. 337)
19. False (see p. 70)
20. False (see p. 404)
21. False (see p. 464)
22. False (see p. 406)
23. False (see p. 363)
24. False (see p. 192)
25. False (see pp. 10, 403)
26. False (see p. 196)
27. False (see p. 396)
28. False (see p. 144)
29. False (see p. 319)
30. False (see p. 417)

Chapter II

THE NATURE OF HUMAN ADJUSTMENTS

Behavior as Adjustment

To achieve its purpose of studying human nature scientifically, psychology must make a detailed analysis of man's behavior and experience. But if this analysis were to be made at the very outset, it would obscure the significance of human nature as a whole, because of the great mass of facts that has to be examined. The forest could not be seen for the trees. It is useless to investigate the parts of a machine before we know what the machine does and how it operates as a whole, since the parts receive their significance from the manner in which they function in the mechanism of which they are the parts. Similarly, all the details of human nature—actions, thoughts, feelings and abilities—are processes that fulfill certain functions in the life of the whole man. To take a glimpse at the operation of human nature in its totality must therefore be the first task of psychology.

A broad point of view based on the parent science of biology offers the best approach to the understanding of animal nature in its entirety. The primary function of every organism is to live; and the very nature of life involves activity, change, and adaptation. Human nature, therefore, is not a static entity that merely exists, but a dynamic way of acting and doing. Human nature *is* what human nature *does*. This active process of living does not proceed in a vacuum, but in a constantly changing world whose forces interplay with those of the organism. For an individual merely to live has no significance; he must *live in relation to his environment*. This concept is the key to the psychological approach.

The Nature of Adjustment. The idea of man living in his environment is made more definite by the concept of adjustment. Every organism has many needs that must be fulfilled if it is to keep on living. These needs in man include certain basic bodily demands such as those for air, food, and warmth, and certain social needs such as those for security, approval, and companionship. But the satisfaction of all human needs encounters obstacles that arise from the inanimate world and from the activities of other persons. Consequently, the individual has to be more than active in a constant and routine manner in order to exist. He has to modify and adapt his behavior in response to varying conditions. This variable and adaptive behavior by which the organism and its environment are kept in balance is the process of *adjustment.* Psychology studies how the individual adjusts to his environment in the process of carrying out his life activities.

Some forms of adjustment are studied by other biological sciences than psychology, and a distinction between them can be made, although it is not a very sharp one. Most basically, life is maintained by nutrition, respiration, circulation, and similar bodily processes. These activities enable an organism to exist in its environment, but they are carried out by particular organs or systems of the body, rather than by the animal as a whole. Adjustments such as these are studied by physiology; psychology is concerned with them only indirectly. On the other hand, many adjustive activities such as the production and distribution of goods, the civic relationships of people, the functions of government, and the conduct of nations furnish the subject matter of the social sciences and are studied by sociology, economics, and political science. Psychology is interested in these problems, but more from the point of view of the individual's conduct than from that of the group. Psychology studies those adjustments of the individual that he makes as a whole person, rather than as a system of organs or as a member of a community.

A number of illustrations of typical adjustments will make

this broadly useful concept more clear; after this, an analysis of the details of the adjusting process will be made.

Some Typical Human Adjustments

A Physiological Adjustment—Bodily Temperature Regulation. A precise and basic adjustment that all individuals make to their environments is the regulation of the temperature of the body. The human organism operates with maximum efficiency at an internal temperature of about 100 degrees Fahrenheit, and maintains this level within 1 or 2 degrees. If the external temperature becomes too warm, the body meets the emergency in a number of ways. The capillaries in the skin dilate, exposing a larger amount of blood to the cooling influence of the body surface. Also, the skin secretes sweat, the evaporation of which lowers the heat of the body. When the environment is too cold, the capillaries contract, driving blood from the skin, the body hairs are erected, and "goose flesh" appears. These adjustments are scarcely subject to voluntary control, but are basic activities of the whole organism in relation to its environment.

More complex activities are also evoked by temperature changes. When he is too warm, a man will avoid muscular exertion, retire to a shady place, wear less clothing, and even resort to such an elaborate device as air-conditioning apparatus. Similarly, adjustments to cold involve the use of clothing, housing, heating equipment, and deliberate muscular exercise. Many of man's most complicated economic activities are designed to satisfy this apparently simple need for temperature adjustment.

An Adjustment to Internal Distress—Hunger. Another elemental adjustment that everyone makes is to a deficiency of nourishment that is sensed as hunger. The beginning of the hunger sequence is not clearly known, but it is probable that a shortage of glycogen or sugar in the blood initiates the process. This stimulus causes rhythmic spasms of the muscular walls of the stomach, which increase in frequency and intensity as the individual grows more hungry. The hunger pangs that are felt in

the region just below the tip of the breastbone are the sensations of these internal contractions. Experimental evidence shows that hunger contractions cause an increase of muscular activity in the body as a whole. Even when one is reading or asleep, the stomach spasms coincide with periods of greater restlessness. A primitive animal, impelled by hunger pangs, grows uneasy and roams about. If it encounters food and eats, its hunger ceases and so does its tendency to be active. It is again adjusted to its environment.

In higher animals, including man, the operation of hunger and of its satisfaction is not so simple. A mild and modified form of hunger can be aroused by the sight or smell of accustomed foods, or even by the mere thought of them. The civilized man, too, does not roam about seeking food when he is hungry, but resorts to an elaborate social organization for growing, distributing, and preparing food to satisfy his needs. Even with all this complexity, the pattern of adjustment is essentially the same. A lack of balance between man and his environment arouses him to activity which continues until the equilibrium is restored.

An Adjustment to External Distress—Being Burned. In addition to adjusting the environment to his internal needs, a person must also adjust himself to the impacts of many forces of the environment. Responses to definite annoyances inflicted upon the surface of the body are typical adjustments of this type. If a mechanic accidentally touches a hot soldering iron, he withdraws his hand promptly, thereby preventing serious bodily injury. Such quick and skillful withdrawal is a reaction acquired by experience, for infant animals only writhe and cry when in pain. They respond in like manner to any annoyance, whether internal or external. Adults, having learned how to act under such circumstances, do so much more effectively. In fact, they need not wait for the injury to occur, but may begin withdrawing from an imminent danger before any harm has been done. The inexperienced baby reaches for a bright flame, but the burned child proverbially dreads the fire. Thus

individuals learn to adjust not only to external injuries that have actually occurred, but also to those that are about to happen, or that may happen in the near or distant future.

A Sense Organ Adjustment—Eye Movements. Even when an individual looks at something, he must make some adjustments to do so effectively. To "pay attention" is in large part an adjustment of the body to receive sensory impressions most efficiently. When a man listens intently, he turns the head toward the source of the sound, leans forward, opens the mouth slightly, and is very quiet. All these actions permit the ears to operate with maximum proficiency. Sense organ adjustments of this sort are preparatory to most of the more active muscular adjustments.

A case of a sensory adjustment that has been studied extensively is the movements made by the eyes while reading. Photographic records show that the eyes move by jumps and pauses while reading a line of type. A short part of the line, perhaps an inch to an inch and a half in length, is clearly visible at one time. This span is seen during a brief pause, after which a very rapid short movement carries the eyes to the next fixation point. Good readers make about four brief pauses while reading each line of a book, and go straight onward. Poor readers need more and longer pauses per line, and often make backward movements to look at a word for a second time. These elaborate eye-movement adjustments are acquired as the child learns to read. Poor readers can be retrained by proper techniques of practice.

An Adjustment to a Total External Situation—Driving an Automobile. In most of the activities of everyday life, individuals adjust to broad patterns of coincident situations, rather than to isolated and specific stimuli such as those considered thus far. To a multitude of environmental offerings, the individual makes selective and complicated responses. Driving an automobile is an example of such an activity. A vast number of impressions are perceived together, including the road, atmospheric conditions, stationary objects, traffic signals,

pedestrians, other vehicles, one's own rate of speed, and the presence of a motorcycle policeman as seen in the rear-vision mirror. Adjustive responses are made in a variety of ways, with the steering wheel, accelerator, brake pedal, clutch, and gear shift. The unskilled driver has difficulty in attending to all of these rapidly shifting environmental facts at once, and especially in carrying out properly coordinated reactions with his many interrelated means of response. The beginner is likely to do one thing at a time, attending now to the steering and now to the shifting of gears.

The experienced driver, however, adjusts to the complex situation as a whole, unless it becomes too involved for him because of some unusual emergency. Under ordinary conditions the manual responses are made automatically and without much thought or deliberation. The driver combines a series of movements, such as those involved in starting up a grade after a stop at a traffic light, into a smoothly operating pattern so that they are hardly separate responses, but are fused into a smoothly operating unit. Similarly in walking, reading, eating a meal, taking a photograph, or carrying on a conversation, an entire complex environment evokes a unitary adjustive pattern of behavior.

An Intellectual Adjustment—Solving a Problem. A problem is a situation to which an adjustment cannot be made immediately on the basis of past experience and habit. Most of the adjustments previously illustrated are not problems to an adult, since he knows the solution at once. Finding food may be a problem to a hungry dog, however, and extricating his stalled car from a busy intersection may be a problem to the novice driver. In these cases no ready responses are available to meet the environmental difficulties.

Problems occur in many everyday life situations. They are especially common in school, because the very nature of education involves the attempt to do tasks that are not yet mastered. Problems are not limited to the schoolish sort, however, but appear in business, in professions, in home life, and

in social relationships. An understanding of the nature of problem-solving is obtained by examining the method that is used to reach an answer to some actual problems. The best experimental material for this purpose is of an unusual nature, often absurd in real life, since the problems must be unfamiliar to the subject of the experiment.

Problems

1. If three cats can catch three rats in three minutes, how many cats can catch one hundred rats in one hundred minutes?

2. A farmer who is moving, has a fox, a goose, and a basket of corn. He comes to a river, and the boat will carry only the farmer and one of his charges. Now, if he leaves the fox and the goose alone, the fox will eat the goose; and if he leaves the goose and the corn alone, the goose will eat the corn. How can he safely take them all across the river?

3. For many years a man has worked on an idea for an improved cotton loom. His invention is at last perfected. A few days before he was ready to sign the patent papers, it occurred to the inventor that since the new loom can do twice as much work as the old ones, half the weavers will be thrown out of work. In his own town the great majority of men earn their livings in the mills. The inventor knows what it is to be out of work, hungry, with no prospect of a job. If he patents the loom, it seems to him, great suffering will result among his neighbors, but he will make his fortune and be independent for life. What shall he do?

The first problem is of the "catch" type, to which a quick answer is usually given that is found to be incorrect on further reflection. The second is a typical "serial" problem in which a number of steps have to be worked out in proper sequence. Many real mathematical, scientific, and business problems resemble this one psychologically. The third problem, like most ethical issues, involves the same psychological processes but does not yield to so precise or unqualified an answer.

An examination of the method of attack upon an unfamiliar problem shows that an acceptable solution is not reached immediately. Tentative answers first are formulated; these often have to be discarded before a satisfactory result is

reached. This process usually is termed *trial and error.* Many trials are made in response to the situation, some of which are rejected as incorrect, constituting the errors. Trial and error may take a number of forms. The attempts to adjustment may be overt and muscular. Thus in solving the second problem, one may manipulate actual objects, or move bits of paper labeled as the characters involved. Or one may use abbreviated symbols, indicating the trials by letters or marks on a piece of paper. A further step of refinement is reached when one *speaks* the trials, using verbal symbols instead of more concrete objects for manipulation. Lastly, one can solve problems without any externally observable activity at all, either by silently "talking to oneself" or by visualizing the steps of the solution in imagery. This final process of *thinking* is adaptive behavior of a superior type, yet not essentially different in character from the more overt muscular forms.

A Social Adjustment—Reaction to Personal Frustration. The social contacts of groups of people call forth some of the most subtle and delicate adjustments. Every person wants to gain the approval of the group, to have his merit recognized, and to feel that he has achieved something. These needs, which are discussed at length in a later chapter, are as important in human life as the simpler physiological demands for warmth or food. When they are frustrated the individual is out of equilibrium with his social environment, and adjustive activity is called for.

For example, a member of a committee is blamed and criticized for something that has gone wrong, and feels impelled to make an adjustment. If his past training makes him capable of effective social adaptation, he may show constructive and suitable responses. He may calmly admit his fault and endeavor to secure cooperation to prevent its recurrence. Or he may quietly show exceptional ability along other lines, and thus demonstrate his worth. If he cannot improve the situation unaided, he can consult with more experienced persons. Finally, if he can do nothing, he may successfully "laugh it

off" and forget the incident, continuing to be socially harmonious with the group in other matters. In general, these are desirable ways of dealing with personal frustration.

In some cases, however, the criticized committee member may apply less desirable balm to his wounded self-esteem. He may make excuses and endeavor to turn the blame to someone else. He may adopt a resentful attitude toward the other members of the committee, asserting that they have grudges against him. In other instances, the person may become uncommunicative, retire "into his shell," and daydream about imagined successes to take the place of the real failure. Many other unfortunate adjustments are possible, including worrying, becoming overaggressive, or taking out one's wrath on innocent persons. These inferior reactions to personal thwarting are not really adaptive solutions of the difficulty encountered, but they relieve tension and often make their perpetrator feel more satisfied with himself. They are therefore satisfactory adjustments to the individual, even though socially undesirable.

An Analysis of Adjustments

The adjustments that have been described must be investigated in more detail. A first step in psychological analysis distinguishes the *circumstances* that call forth an adjustment, and the *activities* of the individual that constitute the adjustment itself.

Situation, Organism, and Response. In each instance of adjustment, it is evident that some form or pattern of energy, usually from the environment, exerts an influence upon the individual. This impact or set of circumstances constitutes a *situation.* Situations are events that act upon the sense organs, or receptors, of the individual and signal to him the condition of his environment. The reactions that he makes to these situations may consist of muscular movements, glandular secretions, memories, or thoughts. These patterns of behavior

evoked by situations are termed *responses*. A preliminary formulation of a very important principle may now be made: *the total behavior of man consists in making responses to situations;* or as it is often written:

$$S \longrightarrow R$$

This brief statement is basic to the psychological investigation of any animal activity. The significance of any situation is sought by looking for the response that it evokes; or if a certain form of behavior is observed, a search is immediately made for the situation that aroused it.

Useful as it is, the $S \longrightarrow R$ formula is not complete. As it stands, the formula would imply that a knowledge of the situation enables an immediate prediction of the response. This is not true, because there is another causal factor of great importance. In order to predict a response to any situation it is also necessary to know a great deal about the *organism* that is being stimulated. Throwing a bone toward an animal will cause it to approach if the animal is a pet dog, but will make it flee if it is a wild rabbit. A juicy beefsteak will evoke entirely different responses from a hungry person and from one who is sick. At a baseball game, the same home run brings shouts from the supporters of one team, and groans from the adherents of the other. The place of the organism in the response formula can perhaps be indicated in this way:

$$S \longrightarrow O \longrightarrow R$$

This states simply that the situation acts upon a certain organism which makes the response. Such a statement, however, causes the organism to appear too mechanical an agent, buffeted at the whim of the situation. It is therefore somewhat better to write the formula:

$$\begin{tikzcd} S \arrow[dr] & \\ & R \\ O \arrow[ur] & \end{tikzcd}$$

to show that it is the situation and the organism together that

determine the response. Using a common mathematical notation, we can also write the same idea:

$$R = f\ (O,S)$$

namely, that the response is a function of the organism and the situation, or that behavior is determined jointly by the nature of the individual and by the forces of his environment.

In many psychological experiments and explanations, the term *stimulus* is often encountered. A stimulus is a relatively simple and clearly defined situation, or else some particular part of a total situation that is chosen for study and emphasis. When the runner leaps from the mark at the sound of the starter's pistol, the shot may be called the *stimulus* for his response. The whole *situation*, however, is much more inclusive, involving his immediately preceding preparatory responses, his training to perform in this way, his motives for running the race, and many other factors.

Cause and Effect in Behavior. The adjustments of men and animals are not made erratically or at random. Every act that a person performs is the result of sufficient antecedent causes. The relationship between cause and effect is as true in psychology as it is in physics. The physicist studies physical events to find out what relationship exists between the conditions that are present and the resulting action. Consistent relationships permit prediction, or a statement of cause and effect. Similarly, the psychologist studies the behavior of organisms in various known situations in order to note what preceding events can be counted on to produce a certain result. In general, psychological causes are more complex than physical or chemical causes, but they are none the less operative.

The statement $R = f\ (O,S)$ is an expression of a cause and effect relationship. The causes of behavior lie in a complex interreaction between the nature of the individual and the forces acting upon him. The shorter expression $S \longrightarrow R$ is a more concise formula for cause and effect in certain simpler and more limited circumstances. A puff of air on the

eyeball (S) causes winking (R). Loss of balance (S) causes movements tending toward the restoration of equilibrium (R). The stern glance of the teacher (S) causes the mind-wandering pupil to apply himself (R). In more elaborate activities the total situational pattern is more difficult to ascertain, but it causes whatever response is made.

A corollary which follows directly from the preceding discussion is that *no behavior is without cause.* All responses are the result of stimuli of some sort. Popular opinion has long held an incorrect view of this matter. A child's restless movements are often wrongly designated as "spontaneous"; a sudden thought sometimes seems to come like a flash into one's consciousness as if from nowhere. When erroneous interpretations such as these are made, the observer usually has overlooked important parts of the situation. The infant in his crib is assailed by many stimuli of light, warmth, noises, the contact of his skin with the coverings, and, what is even more important, his own internal processes of digestion, respiration, and the like. These things evoke the so-called "spontaneous" or restless movements. No thought, no act of imagining, not even a dream, is really spontaneous. Some stimulus sets into motion a whole chain of responses, each leading fleetingly to the next, until the observed state of consciousness occurs. The antecedents of a thought are often hard to discover, but causal factors are always present even for the most evanescent of psychological phenomena.

The Characteristics of Situations

The Situation May Be External. All the stimuli that an individual can receive are divided into two principal groups: those which originate within his own body, and those which are external to his body. Since the function of a living organism is to adjust itself to its environment, every individual must receive adequate impressions of external circumstances in order to continue his existence. Every situation acts upon the individual through the sense organs, or *receptors.* Those

sensory mechanisms that make contact with the outer world are known as *exteroceptors*, and include the sense organs for vision, hearing, smell and taste, and the receptors in the skin.

Some of the exteroceptors require a direct contact with the stimulating object. Thus, taste is stimulated only when a substance is in solution at the taste buds on the tongue; cutaneous contact and pressure senses require the direct presence of an object upon the skin. Other still more useful information about the outer world comes through the receptors that can receive stimuli from objects not in direct contact with the body. Vision, hearing, and smell are usually considered in this class. Of course, some stimulating energy from the object must reach the sense organ, even in the case of these so-called "distance receptors." The eye receives only the light waves which fall directly upon the retina. Similarly, the ear hears only those sounds whose waves reach it, and smell is caused only by substances whose minute chemical particles arrive at the receptors in the nose. Some sense organs operate both by contact and at a distance. Warmth may be felt by the radiations from a hot object as well as by the immediate presence of such an object on the skin.

The Situation May Be Internal. Inside the individual's body there is a vast number of other stimuli that influence his adjustments profoundly. The sense organs are not solely in contact with external things, but are also distributed widely throughout the body. One system of these internal sensory mechanisms consists of the *interoceptors*, which are located in the alimentary tract and in the other internal organs. Some of the stimuli received internally result in conscious experiences, such as internal pain, hunger, or nausea. Other internal situations lie below the level of awareness, but cause responses none the less. Thus the balance of oxygen and carbon dioxide in the blood stimulates inner receptors that evoke muscular responses to regulate the rate and depth of breathing. The secondary effect upon respiration may be conscious, but the primary re-

ceptors exercise their function without the accompaniment of awareness.

Another system of internal receptors consists of the *proprioceptors*, which have to do with bodily posture and balance, and with the control of coordinated groups of muscles. These sense organs lie in the muscles, tendons, and joints, and in the semicircular canals near the ear. They function primarily in the simple but essential adjustments of the musculature of the body to its position and movement, but are also important in the more complex matters of preparatory responses and attitudes.

Popular opinion places great value upon another apparently "inner" source of behavior, namely, that which is "in the mind," or presumably, entirely in the central nervous system. Scientific psychology takes a rather different view of this matter. It is obviously true that people think, remember, and have images, and that these phenomena are important parts of the total pattern of adjustment. Psychology considers these events as *responses*, however, not as self-initiated stimuli. A thought or idea is not an isolated state of mind, but an intermediate response occurring between the original situation which initiates behavior and the final response that accomplishes an end. All behavior originates from situations which may be "outer" or "inner." "Inner" always means *in the body*, however, *not* in some mysterious realm of mind, spirit, or consciousness.

The Situation May Be a Previous Response. The individual not only lives in his environment, but also acts upon his surroundings and modifies them. The performance of one response often brings about a new situation which calls for a further adjustment. In writing a word, for example, each letter that is written is an important determiner of the one that is to come next. In the process of thinking, one phrase or idea is often the stimulus which provokes a further thought. This aspect of situations cannot be described more fully until certain

characteristics of the response have been studied, and therefore is postponed to a later section of this chapter.

The Situation May Be a Relationship. Individuals respond directly to certain *relationships* between stimuli, as well as to the stimuli themselves. In many instances, indeed, it is difficult or impossible to respond to a pure or isolated situation. Behavior is more frequently set off by the interaction of numerous elements of the total impression received from the environment.

Direct responses to relationships are illustrated by many experiments both with human subjects and with lower animals. For example, a hen may be trained to peck at grain only from the darker of two gray boxes that have been presented. This is accomplished by permitting her to eat only from the darker box, and by punishing her if she goes to the lighter one. The positions of the boxes are varied from trial to trial, so that the shade of the box, not its location, is the only cue. After this training has been completed, the hen is presented with the dark gray box of her earlier trials, paired with a still darker one. Rejecting the very box with which she was trained, the hen will now go to the new box which is of the darker shade. It is quite evident that the hen is not responding to a certain shade of gray, but to a relationship, namely, to the situation "the darker of two."

Many simple and complex human responses are similar in principle. A human subject can be taught to identify a certain shade of red among a number which are darker or lighter. He will continue to select the same red under a wide range of intensities of illumination. The physical value of the color is much brighter and much more red in direct sunlight than in a dusky corner of a room, yet the specimen selected is the same in either case. In general, individuals do not perceive and remember a "pure" color, or simple stimulus, but the relationship between the color and the general degree of illumination present at the time.

Another example of this principle can be discovered by an

informal experiment. Ask a person who has just looked at his watch what time it is. In a large number of instances he will be unable to reply without looking at it again. The reason is that the watch-stimulus in the first instance did not answer the more general question, but instead told the person "can I catch the streetcar," or "do I have time to finish reading this chapter," or "how much longer will this lecture last." Thus his response to his watch was to a relationship with some personal problem of the moment. The watch-stimulus fitted into this relationship without being an absolute stimulus for a response of noting the exact time of the day.

Situations Are Organized Wholes. The responses to relationships fall within a still broader generalization. *All* situations to which individuals respond are organized wholes, rather than merely collections of isolated and separate stimuli. So many stimuli assail an individual both from the outside and from the inside that he cannot possibly adjust to them effectively unless they are combined into a unified pattern. A person cannot attend to and comprehend a large number of separate units of experience at the same time, but he can respond to a broader type of situation that combines many such units.

An everyday example of this important principle is found in the process of reading. A mature reader does not spell out words letter by letter, but recognizes each word at a glance. If a long but familiar word such as "university" is exposed to an observer in an apparatus that shows it for only one-tenth of a second, he comprehends it with no difficulty. Yet that length of time is sufficient to note only three or four letters that are not organized into a familiar word. The principle is also true with simpler and less academic situations. If, when you are blindfolded while playing a game, someone pushes you into an upholstered chair, you respond to the entire pattern in an immediate and unitary manner. The whole complex of stimuli means "pushed into a chair," and you respond to it as such. You do not make an analysis of your detailed sensations of position, movement, pressure, and skin contact.

These are instantly combined into the pattern which is the real situation.

There is some evidence that the tendency to respond to whole situations is an intrinsic and natural characteristic of behavior, and not merely a learned way of putting together things that were initially separate. The young child sees *objects*, not stimuli. The red ball on the table is an elementary situation, though a complex one. It takes a much more sophisticated and artificial approach to see the stimuli of redness and roundness abstractly and apart from their presence in the unified pattern of the whole object.

Throughout the study of psychology many illustrations will occur which show that the situations arousing behavior consist of internal stimuli and external stimuli organized into patterns and relationships. Behavior is determined by these integrated whole situations rather than by the separate physical forces of the environment and the body.

The Organism

Responses Are Determined Jointly by the Organism and the Situation. Responses cannot be predicted from a knowledge of situations alone, for such a prediction also requires considerable information about the organism which is to make the response. The *structure* of the organism, its *present organic condition*, and its *past experiences* are all important factors in determining what behavior will be displayed in a given circumstance. One and the same situation will evoke different activities in different organisms, and will evoke different activities from the same organism at different times.

The most elementary consideration in the determination of any response is the *species* of the organism. It is obvious that even in very similar situations, each animal uses the type of locomotion characteristic of its kind. A fish swims, a bird flies, a mammal typically jumps or runs, and nothing can cause an organism to make a type of response for which its structure is grossly inadequate. More subtle differences are of greater

interest because they are sometimes misunderstood. Men speak an organized language, and apes do not, which is usually considered as entirely due to the superior "intelligence" of man. Differences in mental ability are important, but do not tell the entire story. In one experiment (Kellogg, 1933) a young chimpanzee was treated in an entirely human manner, and its development was compared continually to that of a child of about the same age. Neither the child nor the ape learned to talk during the experiment, but the ape's comprehension of language equaled, and in some instances exceeded, that of the child. Yet they differed strikingly in making articulate sounds, the child greatly excelling the ape in the variety of language-like utterances. The ape made few "random" noises, as compared to the wealth of the baby's prattle. The general structural organization of the ape is inferior in its adaptation to spoken language. This includes the entire motor mechanism of voice, as well as the more definitely neural structures that are basic to "intelligence."

Among individuals of the same species considerable differences of structure also exist. The nervous systems of all men are not equal in their potentialities for complicated and superior behavior. The differences between the feeble-minded, the normal, and the mentally gifted are important determiners of behavior. In addition, differences in size, strength, skill, and even beauty are significant in causing variations of adjustments to similar situations.

Responses Are Determined by Organic States. Even the same person responds differently to situations from one time to another. One chief factor causing these variations is the organic state of the individual. Hunger illustrates the meaning of an organic state very clearly. Consider an assortment of foods placed before you (a) when you have just eaten your fill; (b) when you are moderately hungry; and (c) when you are famished. Your behavior toward the food will differ for each of the three organic conditions. In (a) you will remain indifferent, in (b) you will be selective and deliberate in your

choices, while in (c) you will eat anything or everything of a reasonably edible nature that is set before you. The organic state determines the speed, the intensity, and the selection of the response.

Physical health or disease markedly changes a person's reactions to situations. If the delicate chemical equilibrium of the body is upset, as by the excess of blood sugar found in diabetes, profound alterations of the individual's ability to adjust may occur. Toxic conditions influence behavior greatly, as in the case of persons suffering from alcoholic intoxication. The secretions of the glands, especially of the endocrines which secrete directly into the blood, are very significant in determining whether an individual will be slow or alert, irritable or passive, energetic or apathetic. Since these chemical influences are exerted upon all the tissues of the individual as a whole instead of through specific neural action, they illustrate the fact that behavior is a function of the entire organism, rather than of any of its particular systems.

Responses Are Determined by Past Experiences. In the everyday run of the affairs of life, the most important determiner of the response made to a situation is the past experience of the individual. All animals *learn*, and each future response may be modified because of the results of responses made previously. The phenomenon of learning, or the modification of subsequent behavior on the basis of past behavior, is so far-reaching in its importance that it pervades all the topics of psychology. Without investigating the process of learning it is impossible to understand individual development, habit formation, voluntary activity, understanding, remembering, or thinking. Since the topic of learning, then, will occupy so much of the entire study of psychology, only an illustration of its significance is given here.

Suppose that the average American student opens a book printed in the Chinese language. It is a meaningless and confused series of scrawls to him. He does not even know where

to start, or in what order to look at the characters. To the Chinese scholar, however, this same physical occurrence of looking at the book is an entirely different psychological situation, for he is able to read and understand the content. In one sense, the "stimulus" is the same in either instance, but the book is a different *situation* to the Chinese than to the American, because he is a different organism. This difference is not native or physiological, but entirely due to the factor of past experience.

The effect of past experience may be considered as an example of the broader principle of the effect of bodily structure. Learning occurs through modifications of the nervous system. Every act that an organism performs makes it not quite the same organism as it was before. Memories and past experiences are not stored away "in the mind" as so much conscious stuff. The past exerts an influence on the present only through the bodily modifications that have persisted to the present time. The organic state of the individual is thus molded not only by the inherited structure of his species and by his present physiological condition, but also by the entire past history that he has experienced.

The Characteristics of Responses

A Response May Consist in Doing Something—Behavior. Responses to situations are of two principal kinds. When confronted with a total pattern of internal and external stimuli that demand an adjustment, an individual may *do something* and he may *be aware of something*. The first type of response—performing some act—is termed *behavior*, and the second kind—awareness—may be called *experience*.

Animals and human beings have only two types of organs for making reactions: *muscles* and *glands*. If food is placed a few feet away from a hungry dog, he moves toward it. This is a muscular reaction, involving the coordination of a large number of muscle units. In the same situation, the dog will probably also secrete saliva, which is a glandular reaction.

No other types of reaction exist except these two. Gross and extensive muscular and glandular reactions are among the easiest of psychological data to observe and study. Equally important in behavior as a whole, however, are minute and subtle muscular and glandular reactions that may escape the detection either of the individual himself or of external observers. Slight muscular tensions, small changes in posture, and internal glandular secretions are some of the more delicate data of behavior that must be considered in giving a full interpretation of the activities of an individual.

A Response May Consist in Being Aware of Something—Experience. In addition to arousing overt behavior, a situation usually causes a state of awareness or consciousness of present events, which may be supplemented by a more complex awareness of the past or of the expected future. These conscious or "mental" occurrences are the traditional subject matter of psychology, which only in recent years has been giving primary attention to the more significant topic of the total behavior of the organism. Experiences are of a different stuff than reactions, but are none the less real and important, and no more mysterious or difficult to investigate. The chief difference between behavior and experience is that any number of people can observe the same behavior take place, while an experience can be reported only by the person who has it. If you raise your arm—an act of behavior—anyone within seeing distance can record that you have done so. But if you have a toothache—an experience—you are the only person in the world who can report that particular pain. In spite of this, no one doubts the "reality" of toothaches! A stone is known to be "real" only because many observers report the same experiences from seeing, touching, or lifting it. Similarly, since pains, feelings, sensations, images, and thoughts are universally reported to exist, they must be accepted as ordinary natural phenomena and worthy of scientific investigation.

The sources of experience may be divided into three convenient groups. Many experiences are responses of the extero-

ceptive sense organs and of the connected neural tracts, stimulated by external events. By such experiences we are aware of the outside world of the moment. The second group is not sharply distinguished from the first. It consists of the awarenesses originating from the activity of certain interoceptors and proprioceptors that lie within the viscera and the muscles. These, too, are sense organ activities; but since the receptors are located in the body, they result in an awareness of reactions that are already in progress. Thus a stimulus may cause a muscular reaction directly through the nervous system, and the awareness that the act is taking place may come afterward into the field of consciousness. A knowledge of the meaning of a situation arises from this awareness of our reaction to it, as well as from the direct experience of the situation itself. For example, a certain situation may evoke a conscious state of disgust. This quality of awareness arises largely from the muscle tensions of withdrawal from the object, and from unpleasant visceral responses to it, such as those of nausea. The disgust is felt as "inner" and as belonging to the *person* rather than to the object. "It disgusts *me*" is a report of self-consciousness as well as of consciousness of the environment.

The third source of awareness is found in remembering, imagining, and thinking. An external stimulus "reminds you" of a past event. The arousing situation is a present one, but the state of awareness includes many things not directly available to the sense organs. This class of experience is undoubtedly evidence of a complex activity of the higher parts of the central nervous system. Recall, images, and thoughts are experience responses to situations, the physiological seat of these experiences lying chiefly within the higher neural structures.

Responses May Be Emotional. Several common patterns of behavior and experience are worthy of specific description. One of these is emotional behavior, an integration of behavior and awareness of considerable importance in human life. The response to an annoying situation includes more than gross muscular movements. Such a stimulus also sets up a

profound bodily reaction that is difficult to observe except with precise instruments. Changes occur in heart beat, in breathing, and in blood pressure. Digestive movements of the stomach cease, the adrenal glands secrete excessively, and large amounts of sugar are supplied to the blood from the liver. The awareness of emotion arises partly from the inner sensations of these bodily changes, and partly from the operation of certain brain centers.

In primitive life, and in early childhood, vigorous muscular responses almost always are a part of emotion. The child fights, or flees, or has a tantrum. Adults have learned to prevent these overt expressions, but the internal changes are less easily controlled, and may occur even when the individual does not want to become stirred up. The intense emotional response has a disorganizing effect on other processes of behavior and thinking; hence the aroused person is less skillful, less careful, and less capable of making fine discriminations.

Responses May Be Inhibitory. The response to a situation may consist in *not* doing something. The failure to perform an act when at least some part of the situation calls for doing it, is termed *inhibition.* If a person starts to cross a street, his response to an approaching automobile is to stop walking. This is just as positive a response as the performing of an act. Inhibition, in this common sense, is brought about by the innervation of an opposing set of muscles which prevent the forward movement of the response. Inhibition is thus not an omission of an act, but a definitely positive restraining process.

Inhibition also occurs in awareness. It is commonly noted that one often forgets the name of a person whom he dislikes. Upon meeting that person, an adequate stimulus for recalling the name is present, yet he cannot make the appropriate response. Psychologically similar is the plight of the student who, under the stress of an examination, cannot recall a fact that he will remember readily the next day. Like inhibitions of reaction, inhibitions of recall are active processes, not merely absences of activity.

Responses May Be Discriminations. Most situations of everyday life are complex and do not call for a single indisputable response. The individual has to select the features of the total situation to which he will respond, and has to choose from among the several reactions that he can make. Discriminative behavior, while very complex, occurs constantly in the course of life. If a situation presents the possibility of having either pie or cake for dessert, an individual responds to one and inhibits his response to the other. The process of discrimination is achieved in all situations by making some responses and inhibiting others. It involves the active refraining from doing one thing, as well as the positive step of doing the other.

The student must not suppose that some part of the individual sits like a tiny but wise judge to decide what will be done in discriminative behavior. Discriminating is a function of the whole person, just as any other psychological response is. It is influenced by all the factors which determine other forms of behavior. The individual's structure, his organic state, and what he has learned in the past determine his decisions just as surely as they determine his simpler actions. Discriminations can be predicted as certainly as can other responses, provided enough is known about the organism and the situation.

Responses May Be Attitudes. Some very important responses are accomplished by slight muscular movements that have their effect chiefly on the person who makes them. Such responses are best designated as *attitudes*. Everyone knows what it means to "strike an attitude" of pompousness, or attention, or aversion. Each consists of a typical set of muscular tensions and slight movements resulting in an appropriate posture. Actors, and youngsters who are "showing off," exaggerate these attitudes for the sake of the impression on the observer. Every person assumes many attitudes, however, not to display his feelings, but as a part of his reactions to situations. Elementary attitudes, such as attraction, aversion,

or doubt, are abbreviated traces of movements that were made more completely at an earlier and more naïve period of individual development. Complex attitudes, such as attitudes toward war, toward religion, toward the theory of evolution, or toward the income tax, are elaborations of simpler attitudes, and also include elements of remembering, thinking, and imagining.

Attitudes frequently serve as *preparatory responses* which facilitate or hinder the more complete or overt responses to situations. The campaign orator first tries to secure a favorable attitude by citing generalizations or slogans to which all will agree. After enthusiasm is aroused, it is easier to bring about specific activity on behalf of his candidate. The same principles of preparing a desirable set or readiness are present in salesmanship, teaching, and many other professional activities. Even quite elaborate attitudes, however, are not so much "in the mind" as in the muscles. They are partial and incipient reactions to situations.

Many Responses Are Serial. In most instances, a man does not make one single response to an external situation, and then have to be stimulated anew before making another motion. More often an external situation sets off a whole sequence of activities. The completion of the first of these reactions is the stimulus to make the next one, and so on through a long series until a final consummatory end result is attained. Some serial responses are highly organized, so that they constitute an integrated unit. Examples of these serial responses are found in well-automatized habits, such as writing one's name, reading, reciting a well-learned poem, or operating a complicated but very familiar machine.

Other serial responses are not so highly automatic, but each step has to serve as a stimulus for the next one. The common process of revery, or "mind-wandering," is an illustration of this. Starting with a present situation, the individual recalls some past event, which in turn is a stimulus to recall some other associated memory. The process may continue until some

stronger stimulus intervenes and causes him to begin a new line of activity. Far from being random or unpredictable, revery, as a form of "uncontrolled free association," offers good evidence of cause and effect in serial behavior. In one instance the following sequence was recorded in the laboratory. A *shoehorn* was presented visually as a stimulus and resulted in the following chain of thoughts: shoes—shoe store—Fifth Avenue—bus—automobile—crowds—coming from suburbs—street cars—poor service—late for class—reprimand from instructor. Thus a shoehorn leads eventually to classroom attendance! Yet every step in the process is clear when a sufficient record is made of the intermediate stages. All apparently irrelevant thoughts that seem suddenly to "pop into your mind" really have an adequate causal history behind them, which can be discovered if sufficiently careful observations are made.

Responses Are Organized Wholes. A total response is not a collection of unrelated movements, attitudes, and ideas, but is an organized whole. An individual who is responding to a situation orients all his behavior in relation to that situation. Although responses may be broken down into reactions, experiences, inhibitions, discriminations, and the like, for purposes of psychological analysis, they do not exist in this severed form in real life.

Evidence indicates that the whole-body organization of responses is an original condition typical of all animal species, and not just a coordination of originally separate movements. Growing tadpoles achieve their earliest locomotion by wiggling the entire body. Even after legs have developed physically, they move at first only with the trunk, independent movement being a later acquisition. An infant responds to stimuli by acting-all-over. His subsequent more skillful behavior is a new and improved kind of organization which develops from the earlier primitive integration. It is not an integration that springs up where none existed before.

The same form of organization is found in highly learned

performances. A baseball pitcher practices his skill as a unit. He cannot acquire facility in each separate element of pitching and then put the parts together. Instead, the response develops as a coordinated whole from the very beginning. The pitcher will have great difficulty even in describing how he pitches, and if he tries to pay attention to each detail of the action, he is likely to pitch very badly.

All responses, then, are coordinated fusions of considerable complexity. Entire responses can be analyzed into parts for the purpose of studying them, but the parts do not convey all the characteristics of the whole.

Summary

A fairly satisfactory preliminary picture of the operation of men and animals can now be seen, which will serve as a basis for the more detailed descriptions which constitute the subject of psychology. Living organisms are mechanisms that function in an environment. They differ from inanimate machines because they are more complex, because they are susceptible to more numerous and more delicate influences, and because they have active needs brought about by the conditions of their own tissues. The function of a living organism is to adjust to the environment in order that it may go on living.

The adjustment process is carried out by making responses to situations. The organism constantly is affected by the stimuli from its own body and from the outer world. To these influences it responds by doing things muscularly and glandularly, and by experiencing an awareness of what is occurring. The scientific study of the sources and nature of behavior and of the conditions affecting experience or awareness leads to an understanding of the rôle of man in relation to his environment. To achieve this is the aim of psychology.

Chapter III

THE BODILY BASIS OF BEHAVIOR

Man is a vastly complicated mechanism that functions by making responses to stimuli in order to adjust to his environment. The preceding chapter surveyed the operation of the human organism as a whole in terms of the situations that arouse him, and the reactions and experiences that emerge as the products of his activity. The next step in the analysis of human behavior requires a study of the machinery by which these processes are carried out. This calls for an examination of the bodily basis of human nature, or the structures of the organism by means of which responses are aroused, coordinated, and performed.

Of the various structures of the body, psychology is interested especially in the *nervous system.* This complex but highly organized system of living tissues coordinates all the other parts of the body and determines their potentialities for behavior. Whatever an animal is, the kind of existence it leads, is determined by the nervous system with which it is provided. The simple, unspecialized bodily organization of the amoeba creates for it a simple world and a simple life. The more highly specialized nervous system of a bird opens up a more complex world, resulting in a more varied existence. For man, whose nervous organization is most complex and most highly specialized, the world is most extensive and differentiated, and his life is, accordingly, most varied. The world in which an organism lives, and the kind of life it lives, depend upon the structure and the functioning of the nervous system it possesses.

The Nervous System

The nervous system is significant to psychology because it is the mechanism of the stimulus and response process. It is made up of a vast number of fibers that extend from every sense organ, and go to every muscle fiber and gland. If, for example, a man steps on a tack and immediately lifts his foot, he does so because of the action of the nervous system. The tack stimulates sense receptors in the skin of the foot; from these the neural impulses pass up the nerve fibers to the spinal cord and the brain. In the spinal cord and brain the impulses are coordinated and directed into the appropriate outgoing channels. These impulses pass downward in nerve fibers to the muscle units of the leg, stimulating them to contract. All adjustments and responses are carried out in this manner through the action of the nervous system, although many activities are much more complex. This simple preliminary account of neural action will be amplified by many more details in the present chapter.

The Principal Neural Structures. The entire nervous system of a vertebrate animal has three principal parts: (1) the *central nervous system,* which consists of the brain and the spinal cord, and controls all the activities of the organism; (2) the *peripheral nervous system,* which comprises the nerves that branch out from the central nervous system, and which carries impulses to and from every part of the body; and (3) the *autonomic nervous system,* which controls automatic behavior such as heart action.

The central nervous system is of the greatest significance to psychology. It consists of an elaborate series of structures with many subdivisions, some of which will be described in later sections. The two most prominent divisions are the spinal cord and the brain. The parts of the brain may in turn be divided into two great functional groups, namely, the "lower" brain centers that control the simpler and more essential life processes, and the "higher" brain centers that are concerned

with the more complex experiences and the more skillful adjustments. The higher brain centers lie chiefly in the fore-brain, which is the *cerebrum* of the mammals, including man.

Nervous Systems: Simple to Complex. The central nervous systems of all vertebrate animals have the same essential parts, from fish to man. Fig. 2 shows the central nervous systems

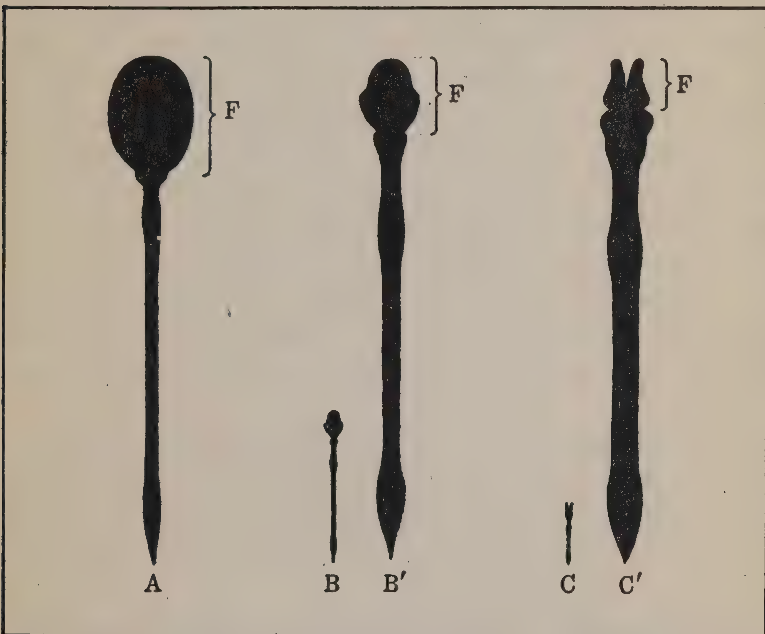


FIG. 2. Central Nervous Systems of Man, Cat and Frog.

A is an outline of the central nervous system of man, and *B* and *C* represent those of the cat and frog respectively, drawn to the same scale. Even when the entire nervous systems of the cat and frog are enlarged to the same length as that of man, as in *B′* and *C′*, the fore-brain (*F*) of man is much larger.

of the frog, the cat, and man, drawn as if they were of the same total length. The essentially similar parts can be identified in the figure. The long spinal cord is topped by the lower brain structures, and these in turn by the fore-brain or cerebrum.

Even when reduced to the same size as that of the frog, the nervous system of man shows some striking differences. His brain is large as compared to the rest of his nervous system. The lower brain centers are not so much larger, but his huge fore-brain, or cerebrum, dominates his entire neural structure. This is the feature that gives man the potentiality for his much more complex behavior. The great growth of his fore-brain is accompanied by a corresponding change in its function. The behavior of lower animals is fixed and automatic to a much greater extent than that of man, and this is provided for adequately by the spinal cord and lower brain centers. A frog with its fore-brain removed can jump, swim, eat, and carry out most of its usual life activities. The casual observer would see nothing abnormal in its behavior. But a man without a cerebrum would be a complete idiot, quite unable to make the adjustments typical of his species. As the cerebrum or fore-brain develops in size and complexity, it takes over more and more control of the finer aspects of experience and behavior.

The Development of the Human Nervous System. The development of the human nervous system during the embryonic period bears some resemblance to the development in the vertebrate series. The human nervous system begins with a line of cells down the back of the embryo, known as the neural plate. These cells fold inward and form the *neural tube,* from which the spinal cord and brain develop. The walls of the lower part of the neural tube thicken, forming the spinal cord, which even when mature has a tiny canal at its center that shows its tubular origin. At the top of the neural tube growth is very rapid, and the characteristic brain structures develop. By the third month of prenatal life, the chief portions of the brain have taken form and can be identified clearly. Thus the human brain in its growth develops from a simple and general structure to one that is complex, specialized, and dominated by the higher brain centers.

Neurons and Nerves

Neurons. Like all other living parts of the body, the nervous system is composed entirely of cells. The structural unit of the nervous system is the *neuron,* a highly specialized, irritable cell that can conduct an impulse throughout its length and transmit it to another nerve cell or to a muscle or gland. Although neurons vary considerably in form, each has certain essential parts (Fig. 3). The broadest part of a neuron is the *cell body,* which contains the cell nucleus and serves chiefly to nourish the neuron by absorbing food substances from the

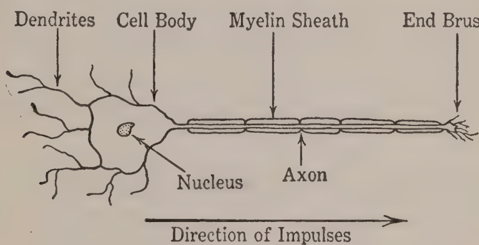


Fig. 3. The Neuron and Its Parts.

Many *dendrites* may spring from the *cell body,* but only one axon. The axon is usually covered by an insulating sheath of fatty substance, the *myelin.* An axon typically is very long as compared to the other parts of the cell, often attaining several feet in length. A neuron conducts impulses in one direction only, from the dendrites to the axon.

blood. From the cell body emerge two kinds of branches, the *dendrites* and the *axon.* The dendrites are usually short stems that break up into fine tree-like endings, except in certain sensory neurons, whose dendrites may be quite long. Each neuron may have a large number of dendrites, which pick up impulses from neighboring cells and transmit them toward the cell body. The axon, of which each neuron has only one, usually runs a longer course, giving off side-branches or *collaterals*, and ending finally in short terminal branches called *end brushes.* A neuron conducts its impulse in one direction only, from the dendrites to the axon.

Types of Neurons. There are three general classes of neurons, *sensory, association,* and *motor.* The sensory neurons carry impulses from the sense receptors into the central nervous system; the motor neurons convey the neural currents outward from the cord or brain to the effector muscles and glands. The association neurons connect the sensory to the motor neurons, and form the coordinating network within the central nervous system.

The peripheral branches of the sensory and motor neurons lie chiefly outside of the central nervous system. A peripheral neuron is either sensory or motor; it cannot perform both functions, because it conducts only in one direction. Although the long dendrites of sensory neurons and the long axons of motor neurons pervade every region of the organism, their cell bodies always lie within the central nervous system or closely adjacent to it.

The form of a neuron is often adapted to its function. Sensory neurons are usually *bipolar* or *unipolar* (Fig. 4). In

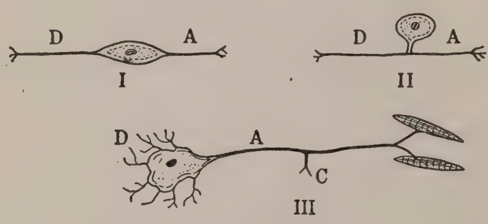


FIG. 4. Types of Neurons.

I, a bipolar neuron, and II, a unipolar neuron, are typical of sensory neurons. III is a multipolar neuron, which is usually motor or central in function. In each neuron, *D* indicates dendrites, and *A* indicates the axon. *C* in the multipolar neuron is a collateral or side branch.

the bipolar neuron, the axon and dendrite emerge from the opposite ends of a spindle-shaped cell body. In some instances, the growth of the cell causes the two poles gradually to approach and fuse together, and to form a single Y-shaped process issuing from the cell body. This is the unipolar neuron.

Motor neurons are typically *multipolar*. They are somewhat spherical in shape, and have numerous short dendrites well adapted to pick up impulses from many other cells. The axon of a multipolar cell often also divides into collaterals running to several effectors. The association neurons, also called central or intermediate neurons, differ little in their essential structure from the multipolar motor neurons. These association neurons convey the neural currents from the sensory to the motor fibers, and also from one part of the spinal cord or brain to another.

The point at which the axon of one neuron makes a connection with the dendrites of another is called a *synapse*. Neurons are in functional contact at a synapse, but they do not fuse together. The impulse is transmitted across a synapse because the action of one neuron arouses the action of the other.

The Neural Impulse. When a neuron is stimulated, an electrochemical change occurs along its fiber. This disturbance is of short duration at any one point, and passes rapidly along the fiber as a wave of excitation. The average speed with which the impulse is propagated in man's neurons is about 100 meters per second. Under normal conditions of stimulation, the nerve fiber conducts a large number of successive impulses per unit of time. In cold-blooded animals, such as the frog, the frequency of the impulses reaches a limit of from 250 to 300 per second. In warm-blooded animals the maximum frequency is higher, reaching about 1,000 impulses per second in the fastest nerves in man.

A neuron fiber is not a passive conductor like a copper wire that carries electricity. The impulse is a biological reaction in the neuron itself, a change of state in which each part of the fiber participates successively. Fig. 5 shows the nature of the neural impulse and the time relations of successive pulsations. Neuron fibers are very efficient, and can be stimulated for hours without appreciable impairment of their operation by fatigue.

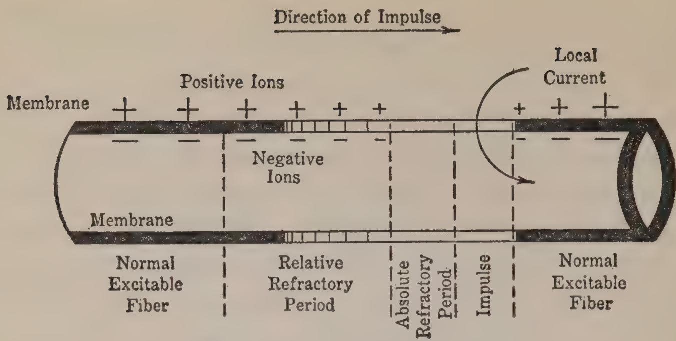


FIG. 5. The Nerve Impulse.

The nerve fiber is shown as a tube with positive electrical charges on the outside and negative ones on the inside. Upon stimulation, the disturbed membrane of the tube becomes permeable, and the positive and negative charges unite. This causes a disturbance in the next adjacent area of the fiber, and so a "wave of excitation" passes along its length. Once a section of the fiber has been activated, as shown in white, it must become restored to normal balance before it can conduct another impulse. This period of recovery is known as the refractory period. First comes the absolute refractory phase while the electrical charges are completely neutralized. They recover their original balance slowly through a second phase, known as the relative refractory period. (From E. G. Boring, *The Physical Dimensions of Consciousness,* Appleton-Century.)

The Refractory Periods of the Nerve Fiber. After transmitting each unit impulse, the neuron rests momentarily. Having been excited once, it cannot be excited again until a normal state of recovery is reached. First, there is a period of complete inexcitability called the *absolute refractory period.* This period may be as long as .01 of a second in cold-blooded animals; it is much shorter in warm-blooded animals, but never less than .001 of one second. This latter figure shows why impulses in a single nerve fiber can never exceed one thousand per second. The impulse frequency of any fiber is determined by the time taken for recovery after its momentary disturbance. Excitability in the neuron returns gradually after the absolute refractory period through a second phase known as the *relative refractory period.* At the beginning of this period, the fiber can be excited only by a very strong stimulus. The stimulation demanded decreases gradually as the fiber recovers its normal

state. It is because of the refractory period that an impulse may pass along a neuron rhythmically, but not continuously. This resting period also explains why neurons are relatively immune to fatigue.

The All-or-none Law of Neural Activity. A single neuron conducts only one intensity of impulse, for if it is aroused at all, it transmits the greatest current of which it is capable. This fact is spoken of as the *all-or-none law.* Neural fibers receive their stimulation either from sense organs or from other neurons. A very slight stimulation will not set the neuron into operation, while a greater stimulus will cause it to transmit impulses of its typical intensity. Above that point, no increase in the stimulus will cause it to respond more strongly. The intensity of the impulse is no greater when the stimulus is strong than when it is weak. This law is analogous to the bullet discharge of a rifle. If a one-pound pull on the trigger of a gun will explode the cartridge, a harder pull on the trigger will not fire the shot with any greater strength. The gun, with the same cartridge, shoots with maximum force or not at all. This analogy is very apt, because the stimulus does not supply the force with which a neuron acts. The neural impulse is an electrochemical action of the neuron itself, and the stimulus merely sets it off, as the trigger does a gun.

It is well known, however, that responses are graduated according to the strength of their stimuli. A brighter light causes a more intense visual experience, and a more severe pin prick causes a more vigorous withdrawal of the hand. How can these facts be reconciled with the all-or-none law? There are two factors that cause a stronger stimulus to evoke a stronger response. First, a stronger stimulus brings *more fibers* into action. Any stimulus falls upon a number of receptors that differ in sensitivity. A very weak stimulus arouses only the most sensitive neuron, while a stronger one will arouse several which require a greater intensity to set them off. Thus fibers of successively less sensitivity are brought into play by a gradually increasing stimulus, resulting in neural discharge through

a greater number of pathways. Second, a stronger stimulus can, and does, raise the *frequency of impulses* that a fiber transmits. A stronger stimulus therefore causes each fiber to conduct a larger number of impulses in each unit of time. Both of these effects operate together and achieve the same result. A more intense stimulus causes *more impulses* rather than stronger ones, both by bringing more fibers into action and by causing each fiber to conduct more frequent impulses. The strength of a response therefore is determined by the *number* of impulses per second that reach an effector.

Nerves. A *nerve* is a bundle of peripheral nerve fibers. The nerve is not a conducting unit itself, but a collection of relatively independent units that have adjacent origins or destinations in the body. A nerve may be compared to a telephone cable which contains a large number of separate conducting wires. The number of fibers in a single nerve differs greatly, from about twenty in the sciatic (leg) nerve of the frog, to approximately a half-million in the optic nerve of the human eye. The fibers that make up a nerve range up to several feet in length. The long fibers are typically motor axons or sensory dendrites.

Most of the fibers in a peripheral nerve are *medullated,* or covered with a thick, whitish, fatty substance known as the myelin sheath. This sheath is believed to insulate the fiber and prevent its impulse from being communicated to others in the nerve bundle. At their extreme terminations, axons lose their sheaths and end as naked fibers. Some neuron fibers are *non-medullated*, or entirely lacking in the fatty sheath. They are grayish in appearance, and occur chiefly as association neurons inside the spinal cord and in the surface layers of the highest brain structures. The non-medullated association fibers do not need the insulation, since their chief function is to conduct impulses freely to adjacent neurons.

The peripheral system, or network, of nerves is simple as compared to the complexity of the central or associative nervous system. The nerve fibers serve to join every receptor to

the central system, and to convey impulses to every effector. The coordination and direction of these impulses are done chiefly in the brain and spinal cord, however. Each nerve fiber runs an uninterrupted path from or to its peripheral destination. There are no connections, synapses, or cell bodies in the peripheral nerves. Synapses exist only in the spinal cord, in the brain, and in certain specialized sense organs such as the eye and the ear.

Cranial and Spinal Nerves. Some of the great nerves issue directly from the brain, and are known as *cranial nerves*, while others that arise from the spinal cord are called the *spinal nerves*. Both cranial and spinal nerves occur in pairs, since the nervous system is completely symmetrical. Fig. 6 shows a ventral view (from the front) of the brain and spinal cord, and the origins of the cranial and spinal nerves.

There are twelve pairs of *cranial nerves* that pass directly from the brain chiefly to sense organs and muscles located in the head and neck. One pair goes to the receptors for smell located in the nose, another pair to the eyes, and another pair

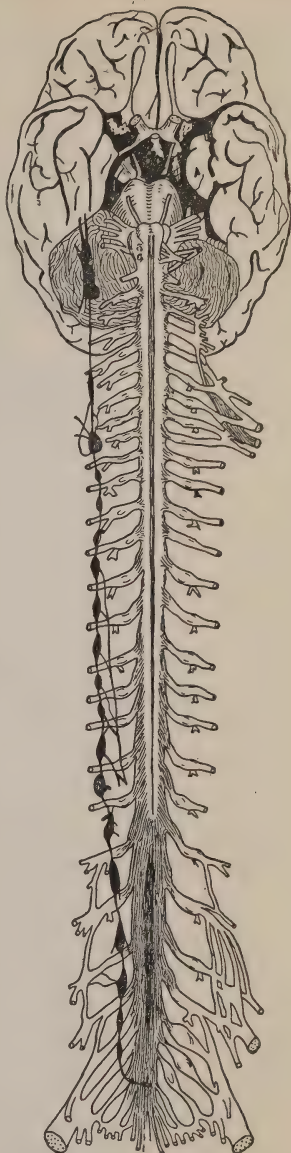


FIG. 6. The Brain and Spinal Cord.

The brain and spinal cord are seen from the front. The 12 pairs of cranial nerves are shown arising from the brain, and the 31 pairs of spinal nerves from the spinal cord. A chain of "sympathetic" ganglia is shown on the left; a similar chain on the right is not shown.

to the organs of hearing and equilibrium in the ear. The sense of taste from the tongue is also transmitted to the brain by the fibers of cranial nerves. Other cranial nerves carry motor impulses to the muscles of the eyes, jaws, tongue, face, and neck. One especially interesting pair of cranial nerves, however, the *vagus* ("wandering") nerves, go down into the trunk and serve the heart, lungs, and digestive organs. The normal functions of breathing and digestion are regulated largely by impulses that pass down the vagus nerves from lower brain centers.

The thirty-one pairs of spinal nerves have their origin in the spinal cord. They emerge between the segments of the vertebral column, one nerve of each pair from the right and one from the left. The spinal nerves are named from the region of the vertebral column from which they originate. There are 8 "cervical" pairs in the neck region, 12 "thoracic" pairs back of the chest, 5 "lumbar" pairs in the lower back, and 5 "sacral" and one "coccygeal" pair in the terminal region. The spinal nerves convey motor impulses to the muscles of the trunk and limbs, and bring in sensory impulses from the receptors located in the skin, the muscles, and the visceral organs.

Lower Levels of Neural Integration

The connecting and integrating functions of the central nervous system are performed at all levels of its structure. In general, the most elementary and fundamental coordinations may be made by the lower centers in the spinal cord and in the inferior parts of the brain. The more complex activities are integrated by the higher nerve centers of the cerebrum.

The Spinal Cord. The spinal cord is a tubular structure that reaches from the brain about two-thirds of the way down the back. It occupies the hollow interior of the vertebral column, through the openings of which the spinal nerves enter the cord. As may be seen from Fig. 7, the cord contains two principal

types of structure. The outer part consists of columns of nerve fibers running up and down the cord and to and from the brain. The fatty medullary sheath of these fibers gives them a characteristic appearance of "white matter." The interior part of the cord is grayish in color, consisting chiefly of cell bodies and of short connecting neurons. The cell bodies belong to the motor neurons that issue forth to the muscles and to the connecting neurons. A pair of spinal nerves leaves the vertebral

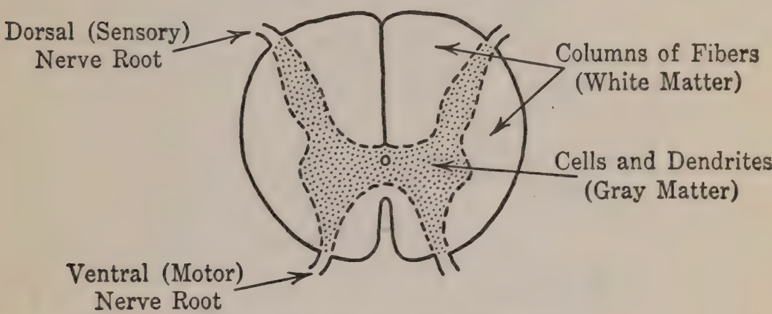


FIG. 7. Cross Section of the Spinal Cord.

The outside part of the cord consists of bundles of nerve fibers that run up and down its length. The central portion or "gray matter" consists chiefly of nerve cell bodies and dendrites.

column at each segment. Each nerve consists of sensory and motor components which unite just after leaving the cord. The sensory neurons all enter at the dorsal (back) side of the cord, and the motor neurons issue from the ventral (front) side.

The spinal cord has three principal functions. First, it is a primary connecting center for some very simple bodily movements known as reflexes. Second, it is an integrating mechanism that coordinates the movements of large groups of muscles and of whole parts of the body. Third, it is a connecting cable that conducts impulses up to the brain centers and down from them.

The Spinal Reflex Arc. The simplest kind of sensory-motor response, the neural circuit of which is the prototype of many more complex ones, is the *spinal reflex*. A reflex is a relatively

simple and automatic reaction, usually performed by a limited group of muscles. An example is the well-known patellar tendon or "knee-jerk" reflex. A tap on the tendon just below the knee cap stretches the quadriceps muscle in the calf of the leg. This stimulates the proprioceptors, or muscle-sense receptors, which send impulses to the cord (Fig. 8). Here the impulses are transmitted to outgoing motor fibers which cause

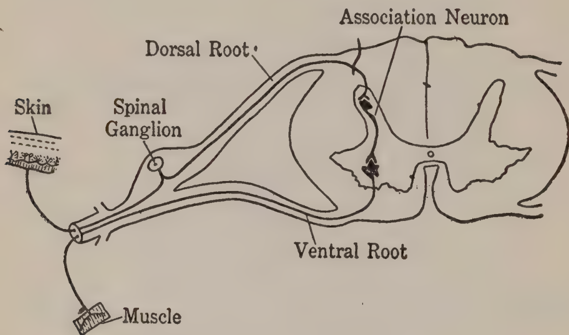


FIG. 8. The Spinal Reflex Arc.

The sensory neuron is stimulated from the sense organ in the skin and conducts impulses into the spinal cord. The cell body of this sensory neuron is located in a "spinal ganglion" adjacent to the cord, and the neuron enters the cord by the dorsal (back) root. In the cord it connects with an association or connecting neuron, which in turn conveys the impulses to a motor neuron, whence they go out to an affector via the ventral (front) nerve root. In any actual reflex, many such arcs operate in a coordinated manner.

the muscles to contract, resulting in a kick of the leg. The simplest nerve pathway that can bring about this reaction is called the *reflex arc.* It may consist of only two neurons, one sensory and one motor, which have their synapse in the cord, but usually there is a third connecting neuron between them, as shown in the figure. Of course, one neuron chain never acts in isolation. In the actual knee-jerk reflex, a considerable number of sensory neurons convey the impulse to the cord, and many motor fibers bring the neural current back to the muscle.

Spinal Integration. The spinal cord not only permits reflexes to operate, but, more significantly, it enables them to work

together harmoniously. It is the lowest center for the integration of total behavior. One form of integration is found in the *coordination* of motor impulses (Fig. 9). A single muscle fiber rarely moves by itself, but large groups of fibers act together. This coordination is effected by branching association neurons that convey an impulse of some sensory origin to just the right combination of motor neurons. In many instances, these association fibers run up and down the cord, coordinating the action of muscles whose nerves originate from several different segments.

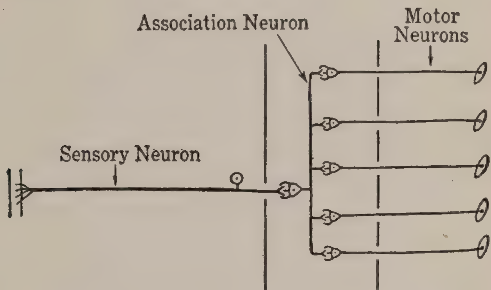


FIG. 9. Spinal Integration—Coordination of Impulses.
The branching association neuron in the spinal cord transmits the impulses from one sensory neuron to several motor neurons. This mechanism causes a system of muscle fibers to coordinate in an effective movement.

Another integrative function is illustrated by the *convergence* of impulses. A given muscle can be moved by impulses from a wide variety of sensory channels. Thus a man may lift his foot because of a verbal command, because of a pain or pressure stimulus on the foot itself, or as a part of the complex rhythmic movement of walking. In every case, the final motor impulses go out to the muscle over the same neuron. A muscle unit has only *one* neural fiber, and every stimulating influence, no matter what its original source, must pass over this *final common path* to reach the muscle. Impulses from many origins thus converge upon each motor neuron in the cord.

Two or more sources of sensory stimulation may find the same final common path to a muscle, thereby making the

response more intense, prompt, and certain. For example, if a loud noise is made just at the moment that the knee is tapped, the knee-jerk reflex will be exaggerated. This is known as the *facilitation* of a response by means of some concurrent kind of stimulation. The opposite effect of *inhibition* also occurs commonly, when the performance of one response prevents some other response or interferes with it. The higher centers of the nervous system also influence spinal coordinations profoundly. Some reactions are facilitated and others are inhibited by the total complex pattern of impulses received from the higher centers.

Projection Pathways. In addition to its connecting and coordinating functions, the spinal cord carries large bundles of fibers up to the higher brain centers and down from them. In general, these long "projection" fibers occupy the portions of the cord around its circumference. Most of the sensory fibers pass up in the bundles along the dorsal (back) side of the cord, and the motor fibers lie principally along the ventral (front) and lateral (side) surfaces. A sensory impulse from the skin passes along a neuron in the spinal nerve, and enters the cord. Here it connects with another neuron whose fiber runs up the cord to an appropriate center in the brain. Fig. 10 shows some connection and projection pathways in the spinal cord. The impulse may pass from the sensory to the motor neuron in the cord itself, or it may pass up the sensory projection fibers to the brain, returning through the motor projection pathways to the final motor neuron.

If the fibers that join the levels of the spinal cord with the higher brain centers are damaged or destroyed by disease, the control of the muscles is seriously impaired. Destruction of either sensory or motor pathways may have rather similar end results. In infantile paralysis certain ventral *motor* centers are destroyed by the disease process. The victim of this disorder cannot move the affected leg because the motor impulses cannot go out to reach it. The paralysis may affect one leg or both, according to whether one or both sides of the cord are

damaged. In another disease, locomotor ataxia, the spinal *sensory* pathways in the dorsal part of the cord are damaged. Here the affected person cannot move his muscles effectively

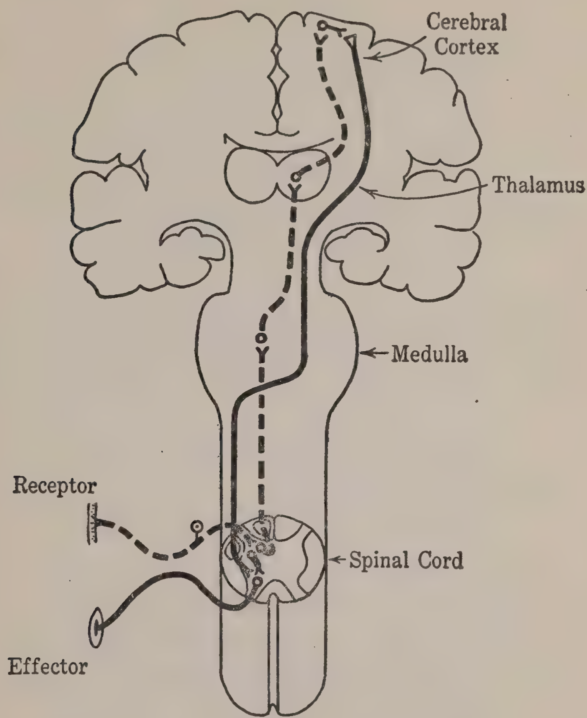


FIG. 10. Spinal Integration—Projection Pathways to the Cortex.

The sensory neuron enters the spinal cord and may connect there to a motor neuron, forming a spinal reflex arc. Or the sensory neuron may connect with sensory projection fibers (shown by dotted lines) which convey the impulses to the cerebral cortex. The sensory fibers typically travel upward in the dorsal side of the cord and pass through the medulla and thalamus. In the cerebral cortex, connection is made to a motor neuron (shown by the solid line) which passes downward, typically in the lateral region of the cord, to reach the final motor neuron. Note that both sensory and motor neurons "cross over," so that the left half of the cerebrum controls the right side of the body.

because he cannot "feel" their positions. The sensory impulses from the muscles that normally control the coordination of a sequence of movements cannot reach the higher brain centers.

The individual therefore walks awkwardly, stumbles, and has difficulty in maintaining his balance.

With a very few exceptions, all sensory and motor neurons "cross over" to the opposite side of the nervous system before reaching the final connecting center. In general, the left side of the nervous system controls the right side of the body, and vice versa. In some instances, the fibers cross over immediately upon entering the cord and go up the opposite side to the higher centers. In other sets of neurons, the projection fibers run up the same side of the cord and cross to the opposite side at a lower brain level, as shown in Fig. 10.

Intermediate Levels of Neural Integration

At its upper end, the spinal cord merges with the more complex structures of the brain. The human brain may be described

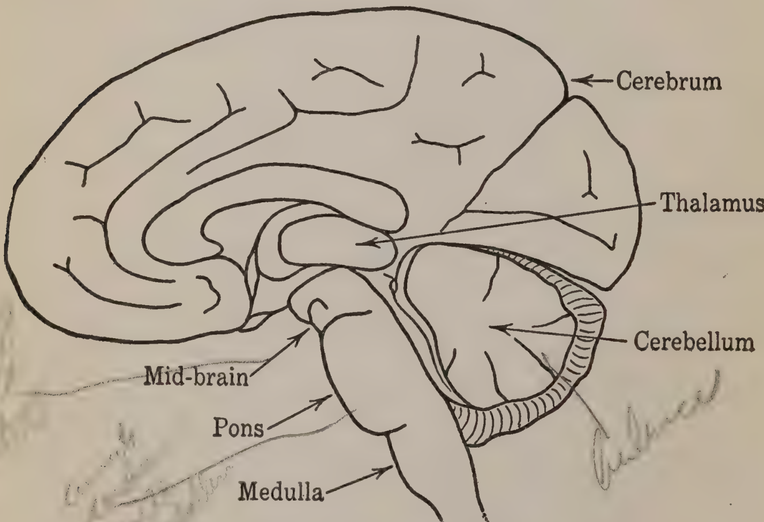


Fig. 11. The Human Brain.

This is a "sagittal" section of the brain, passing from front to back in the middle plane of the head. The great, enveloping *cerebrum* or fore-brain covers most of the lower brain structures. The *medulla* is an enlargement at the top of the spinal cord. Above it are the *cerebellum* and *pons*. The small *mid-brain* lies just above the pons, and the *thalamus* is embedded in the cerebrum.

as a series of parts which assume successively more complex functions from the bottom to the top. Like the spinal cord, each region of the brain consists of *connecting centers* where neural impulses are transmitted across synapses from one neuron to another, and *transmitting fibers* that join the various parts and coordinate their functions. Each of the principal parts of the brain will be described, beginning with the lowest, that is, the part nearest the spinal cord (Fig. 11).

The Medulla. The *medulla oblongata* is a relatively simple structure appearing as a bulbous enlargement at the top of the spinal cord. Large bundles of nerve fibers pass through the medulla from the spinal cord to the higher brain centers. Several cranial nerves also emerge from it, going to the muscles of the face, tongue, and visceral organs, and to the receptors for taste, equilibrium, hearing, and the skin senses of the head and neck region.

The medulla contains connecting centers which control some of the most vital functions, such as respiration and heart beat. Here also are the primary centers for many basic reflexes of the stomach and intestines, and for some simpler auditory, skin, and muscle-sense reflexes. The functions of the medulla are so essential that its destruction results in immediate death.

The Cerebellum and Pons. The *cerebellum* is a large structure lying above and behind the medulla. It is especially connected with the sense organs for equilibrium and with the muscles. The total removal of the cerebellum of an animal results in a complete loss of bodily balance. Its partial destruction, as by a tumor, leads to unsteadiness, lack of muscular tone, a staggering gait, and abnormal postures. These phenomena indicate that the function of the cerebellum is the control of muscular tone, bodily equilibrium, and posture.

The *pons* ("bridge") encircles the upper part of the medulla and is closely associated with the cerebellum. It consists chiefly of bands of fibers that connect the cerebrum with the cerebellum, and also contains some lower motor connecting centers.

The Mid-brain. As compared to his other brain structures, the mid-brain of man is small and inconspicuous. On the external surface it appears only as four small nodules above the pons, known collectively as the *corpora quadrigemina.* Other mid-brain centers lie internally at the same level, but are entirely hidden by higher parts of the brain.

The lower pair of the corpora quadrigemina contain auditory reflex centers. They operate in simple reactions such as "jumping" upon hearing a loud sound. The upper pair function in visual reflexes, especially in the lens and pupil reflexes and the coordination of the two eyes. The motor centers of the mid-brain are concerned chiefly with posture, equilibrium, and muscle tonus, being associated with the cerebellum. The great fiber systems that connect the receptors and effectors with the cerebrum also pass through the mid-brain.

The Thalamus. The thalamus consists of two egg-shaped lobes, one on each side just above the mid-brain, which are embedded in and enveloped by the cerebral hemispheres. Like almost all the principal structures of the central nervous system, the thalamus has both sensory and motor functions. The larger part of it is sensory, and acts as a sort of vestibule through which impulses reach the cerebral hemispheres. All sensory neurons, except those of smell, end in the thalamus, where synapses are made with other neurons which carry the impulses to the final cerebral centers.

A smaller part of the thalamus in man makes connections for some primitive sensory reflexes, serving the most crude protective elements of sensation, such as pain and temperature. Injury to the connections between this part of the thalamus and the cerebral cortex causes all sensations to be excessively painful. The thalamus is believed to be the seat of a vague and simple kind of awareness that is especially important in emotional states.

Higher Levels of Neural Integration

The Cerebral Hemispheres. In man, the fore-brain is represented by the highly developed *cerebral hemispheres* which

occupy about two-thirds of the cranial cavity, and form about one-half of the total weight of the entire brain (Fig. 12).

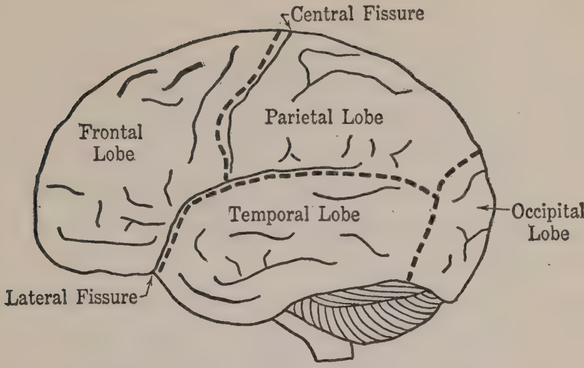


FIG. 12. The Cerebrum.

This is a side view of the left hemisphere of the cerebrum, showing the four lobes and the two principal fissures. The lobes are indicated by the dotted lines.

The hemispheres are divided by a *longitudinal fissure*, but are kept in coordination by a broad band of fibers running between

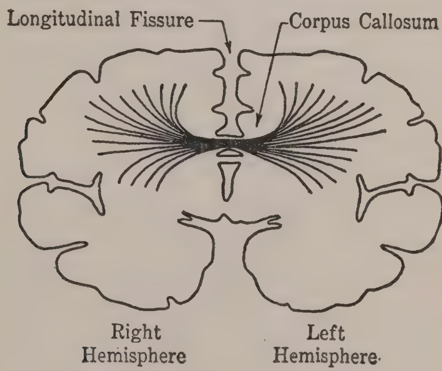


FIG. 13. Cross Section of the Cerebrum.

The cerebrum is cut from right to left to show the *longitudinal fissure* that divides it into two hemispheres. The hemispheres are connected and coordinated by the *commissural fibers* that pass from one to the other in the *corpus callosum*.

the halves, which is known as the *corpus callosum* (Fig. 13). Each hemisphere is deeply indented with other fissures which

serve to increase the surface area. Two of these fissures are especially prominent and form convenient boundaries for describing certain areas of the cerebrum. These are the *central fissure* which divides the front and rear parts of each hemisphere, and the *lateral fissure* which is indented in the side surface. The description of the cerebrum is also assisted by reference to the four *lobes*. The *frontal lobe* lies in front of the central fissure. The *parietal lobe* occupies the middle part of the hemisphere, and the *occipital lobe* is the rear portion. The *temporal lobe* lies below the lateral fissure at each side of the cerebrum.

Functionally, the cerebral hemispheres are divided into the surface "gray matter" or *cerebral cortex*, and the internal "white matter." The *cortex* is the most significant part of the entire nervous system with respect to complicated and adaptive behavior. Here, in a layer of nerve cells and dendrites about three millimeters in thickness, are made the connections for the most specialized activities of the organism. In man, all the more complex conscious experiences depend upon the neural impulses reaching the cortex. All complicated, skilled, and learned movements are coordinated by neural currents that are initiated in this region. The cortex is the essential center that operates in all instances of problem-solving, voluntary action, thinking, and imagining.

To perform these functions the cortex has to be elaborately connected both internally within itself and externally with all other parts of the nervous system. This function is performed by the innumerable fibers that form the "white matter." These fibers are of three kinds: (1) those that connect the cortex with lower parts of the system, particularly the cord, known as *projection fibers*; (2) those that connect different regions of the same hemisphere, called *association fibers*; and (3) those that connect the symmetrical regions of the two hemispheres through the corpus callosum, known as *commissural fibers* (Figs. 13, 14). The total number of fibers in the cerebrum is

very large, conservative estimates running to hundreds of millions.

FIG. 14. Fiber Systems of the Brain.

In I are seen the principal systems of *projection fibers* which connect the cerebrum with the lower brain centers and with the spinal cord. II shows the *association fibers* that connect the various regions of a hemisphere.

The Functions of the Cerebral Cortex. The particular functions of a number of areas of the cerebral cortex have been discovered. Several methods of research have been used to determine these facts. In extirpation experiments, portions of the cortex of an animal are destroyed and observations made of the effects upon sensory discrimination and motor action. Similar observations may be made upon human beings whose brains have been damaged by accidental injury, tumor, or disease. In another type of experiment the cortex is stimulated electrically in limited regions, and the resulting movements

or experiences are noted. Anatomical studies that show the fiber connections of various tracts are also of some value in determining the functions of cerebral areas.

Sensory Areas. Some parts of the cortex are connected to the sense organs, and are essential to the functions of conscious sensation. Man "sees" with the visual part of the cortex as much as with the eyes, for the removal of the particular cortical area concerned with vision results in blindness.

The most primitive of the special senses is *smell.* A small portion of the brain lying in the lower inside portion of the cerebrum near the thalamus is devoted to this function (Fig. 15a). The olfactory receptors in the top of the nose communicate by a stalk of fibers to a very complex set of intermediate centers, ending in a lower central portion of the cortex on the inner surface of each hemisphere. The entire path of the sensory fibers for *taste* has never been determined, but the cortical area is believed to be adjacent to that of smell.

The area for *hearing* is in the upper part of the temporal lobe (Fig. 15b). From the ear, the auditory nerve enters the medulla and rises to the thalamus, where a synapse occurs. The final auditory fibers end in the temporal lobe just below the lateral fissure.

The function of *vision* is performed by a cortical area in the occipital lobe at the rear of the brain and chiefly on the internal surface of the hemispheres adjacent to the longitudinal fissure (Fig. 15c). The path of the visual fibers is peculiar. The optic nerves meet just back of the eyes and the fibers are redistributed, those from the left half of each retina going to the left side of the brain, and those from the right half to the right side. As in the case of hearing, an intermediate connection is made in the thalamus before the impulses reach the cortex.

The neural tracts for the skin and muscle senses terminate in the somesthetic (body sense) area just back of the central fissure in each hemisphere in the parietal lobe (Fig. 15d). Each

side of the body is connected to the opposite side of the cortex, the sensations from the right side, arm, and leg occurring in the left hemisphere, and vice versa. At the top of each somesthetic area are received the impulses from the feet and legs,

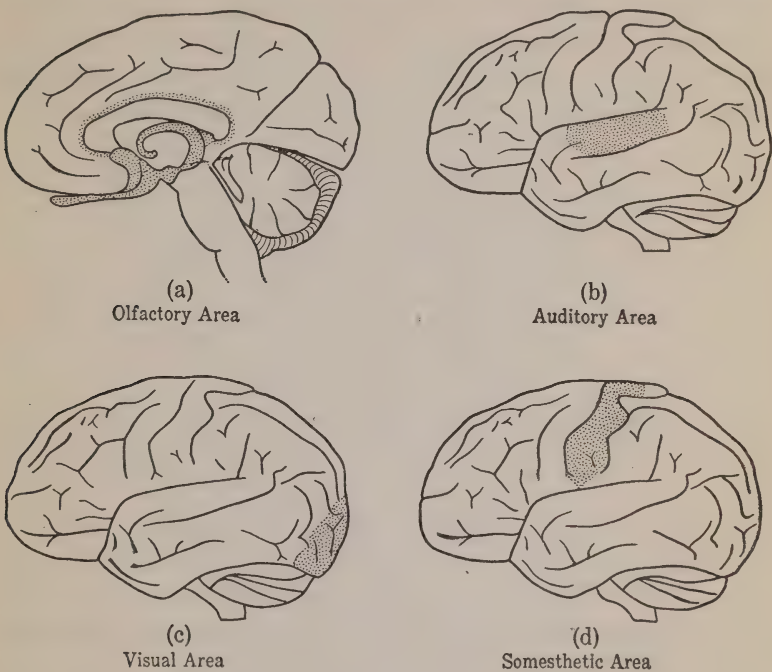


FIG. 15. Sensory Regions of the Cerebral Cortex.

(a) A sagittal or median section of the brain showing the location of the center for *smell*, or *olfactory* center, which is shaded. (b) A side view, showing as a shaded area the *auditory* center in the temporal *lobe*. (c) The shaded region is the *visual* center in the occipital lobe. (d) The *somesthetic* area, for the skin and muscle senses, lies in the parietal lobe, just to the rear of the central fissure.

in the middle from the trunk and arms, and at the bottom from the neck and face.

Motor Areas. The principal motor area of the cortex lies in the frontal lobe, in the portion just in front of the central fissure (Fig. 16). The particular localizations within this region are analogous to those in the somesthetic area just described.

First, the areas of control are reversed between right and left, and second, the lower parts of the body are controlled by the upper parts of the cortex. In the motor area are large nerve cells, termed *pyramidal cells* because of their shape, from which the motor impulses arise. The axons of these cells, which are among the longest in the body, pass through the lower centers, and terminate at various levels of the spinal cord, where the impulse is passed to the final motor neuron. Most of the motor

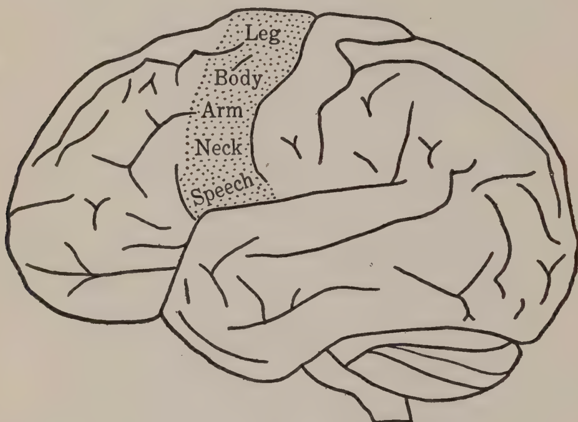


FIG. 16. The Motor Area.

The shaded region indicates the primary motor center of the cerebral cortex, located in the frontal lobe just in front of the central fissure.

fibers cross over to the opposite side at the level of the medulla; others cross over in the spinal cord.

Every final motor neuron receives impulses from many parts of the nervous system. Reflexes from the cord, medulla, and mid-brain, and tonus impulses from the cerebellum are of vital importance. All elaborate and complex coordinated movements, however, originate in the impulses from the motor areas of the cerebral cortex.

Association Areas. A considerable part of the cerebral cortex does not have any definite sensory or motor functions, but acts to coordinate and extend the actions of the specific areas.

Since they serve to connect the impulses from many other regions, these portions are termed *association areas* (Fig. 17).

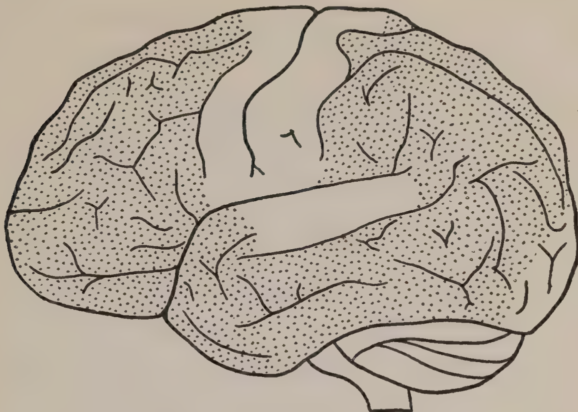


FIG. 17. Association Areas.

The parts of the cerebral cortex that do not have specific sensory or motor functions serve to coordinate the complex learned acts that use several senses and large groups of muscles.

There is some evidence that the association areas normally have functions that supplement those of the specific sensory or motor areas to which they are adjacent. Thus, the frontal lobe is chiefly motor in function, corresponding to the nearby motor area. It coordinates the most complex of skilled movements that require a combined action of several parts of the motor area and connections with several sensory regions. The elaborate system of association fibers (Fig. 14) permits this. Damage to parts of the frontal association area may result in the loss of skilled coordinations. An especially interesting example of this is found in the motor speech area, which lies just in front of the portion of the primary motor cortex that moves the larynx. Damage to this region results in an inability to talk. Sounds can be made, but not words. A person suffering from this damage can often understand speech, and can reply in writing, but not orally. Cases of this sort sometimes result from gunshot wounds of the head or from brain tumors.

The association regions of the occipital lobe, near the visual area, are concerned with higher ocular functions such as reading. A large part of the temporal lobe adjacent to the auditory area functions in the comprehension of language and of other sounds. The parietal lobe is largely an adjunct to the neighboring somesthetic area.

Specialization and Generalization of Function. With what part of the brain does one learn, reason, think, and imagine? The only answer to this question is that these functions are performed by no portion of the cortex singly, but by the combined activity of all the nervous system. These complex mental activities are therefore not localized, but represent the efficient interrelation of many centers. The experiments by Lashley on the brains of rats and monkeys illustrate this fact. He trained the animals to escape from problem boxes, to operate latches, and to perform other similar tasks. Then he operatively removed various parts and amounts of the association areas of their brains. After the operation many animals could no longer perform what they had learned. The loss of learned behavior, however, was more a function of the *amount* of cortex removed than of the area from which it was taken. The more brain tissue removed, the more stupid the animals became.

Under certain conditions, habits that are destroyed by brain damage can be relearned. Lashley found that his rats could relearn the task after the operation if the total area damaged was not too great. Since the destroyed cortical tissue did not regenerate, the subsequent relearning must have occurred in other areas and pathways that had been left intact. In general, a complex habit does not always occupy the same cortical regions or connections, but can be learned by means of a great variety of brain processes. This fact has been used in the reeducation of men after brain damage. After the war of 1914-1918, many soldiers with head wounds were retrained to talk, to walk, and to engage in useful occupations, presum-

ably through the substitution of undamaged association areas for the ones destroyed.

The brain is therefore a unitary organ in its most complex functions, although an infinitely complicated one. The simple vital functions are carried out by fixed neural circuits that are not capable of much modification. The varied and adaptive behavior of the higher organisms, including man, depends upon the operation of the nervous system in a less specific but more flexible manner.

The Autonomic Nervous System

In addition to the peripheral and central nervous systems, there is a third great part of the total neural structure known as the *autonomic nervous system.* This system regulates the action of the viscera, or the internal organs, that serve to maintain the body and to reproduce the species. Among the reactions controlled by the autonomic nervous system are heart action, digestion, excretion, and a number of other processes of the same class. The neurons of the autonomic system are all motor fibers; that is, the autonomic system initiates reactions but does not have any sensory functions. Incoming stimuli are all received through the central nervous system, and certain impulses pass from it to the autonomic system. Anatomically, the autonomic nervous system may be separated into three divisions: the *cranial*, the *thoracic-lumbar* (or "*sympathetic*"), and the *sacral* (Fig. 18).

The upper or *cranial* division grows out of the lower brain centers, and consists principally of the *vagus nerves*, a pair of cranial nerves that have been mentioned previously. These large nerves send branches to the heart, stomach, intestines, and other inner organs. Other functions of the cranial division include the contraction of the pupil of the eye, and the normal secretion of saliva. The lowest, or *sacral*, division arises from lower segments of the spinal cord, and consists of nerves going to the organs of excretion and reproduction. The cranial and sacral divisions are similar in function, and often are grouped

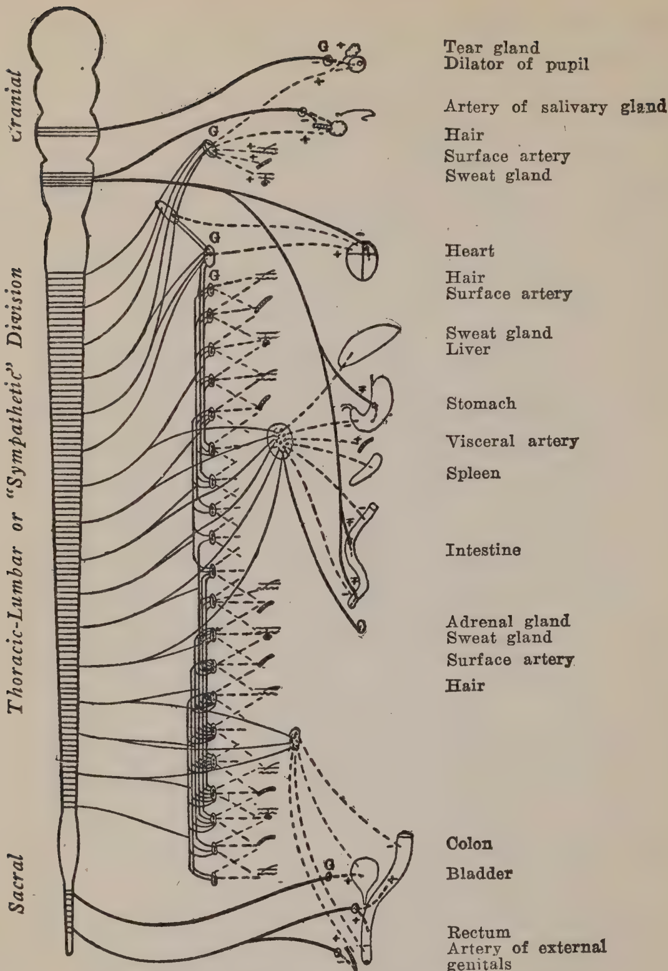


FIG. 18. The Autonomic Nervous System.

The brain and spinal cord are indicated at the left. Nerves from the *cranial* autonomic division go to organs in the upper part of the body, and those from the *sacral* to the lower part. These act together and comprise the *cranio-sacral* or *parasympathetic* division. The *thoracic-lumbar* or *sympathetic* division originates from the middle part of the cord and acts through the chain of ganglia shown. The + signs indicate an accelerating effect on the organ concerned and the — signs an inhibiting or retarding effect. The action of the sympathetic division is antagonistic to that of the parasympathetic. (From W. B. Cannon, *Bodily Changes in Pain, Hunger, Fear and Rage,* Appleton-Century.)

together as the *cranio-sacral* or *parasympathetic* division. In general, the innervation from this division favors the normal functioning of the visceral organs. The parasympathetic division keeps the heart beat down to its normal rate, activates the muscle walls of the stomach to make the churning movements necessary to digestion, and at the same time stimulate the glands of the stomach and intestines to pour forth their digestive juices.

The middle division of the autonomic nervous system, the *thoracic-lumbar* or *sympathetic*, originates from segments in the middle of the spinal cord. The neurons from the cord terminate in the autonomic *ganglia*, a chain of relatively independent neural centers that lie within the trunk cavity and are profusely connected with one another. From the ganglia fibers pass to all the principal visceral organs. Each internal organ therefore receives a dual set of autonomic fibers, one from the cranio-sacral division and one from the sympathetic. In general, the functions of the sympathetic division are *antagonistic* to those of the cranio-sacral. An effector organ that is speeded up by one set of fibers is slowed down or inhibited by impulses from the other. The sympathetic innervation tends to accelerate heart beat, deepen respiration, and stop digestion. The sympathetic division operates principally when an emergency arises in the life of the organism, as when great exertion is needed, when fatigue sets in, or when a strong emotional state such as fear or anger is aroused. The effects of emotion upon the body through the sympathetic division are especially significant, and are described in more detail in Chapter VI. In addition to their connections to internal organs, the sympathetic fibers join the large spinal nerves and pass to all parts of the body. They innervate the muscles in the walls of the blood vessels, small muscles in the skin, and the sweat glands. Hence sympathetic innervation may cause perspiration, the erection of body hairs, the muscular action responsible for "goose flesh," and the dilation or contraction of the small blood vessels. These effects are often present during an emotional reaction.

The Effector Mechanisms

All behavior of organisms is carried out by the *effectors*, or organs of response. In the broadest classification, there are only two kinds of effectors, *muscles* and *glands*. There are two kinds of muscles, *striped* and *smooth*. The glands also fall into a twofold division, *duct* and *ductless*. These groups of effectors are activated by the motor impulses from the nervous system.

The Striped Muscles. The striped, or striated, muscles which bring about the movements of the limbs make up the skeletal musculature of the body. Each group of these muscles is composed of thousands of individual thread-like muscle fibers, or elongated cells, whose special property is that of contractibility. The muscle becomes shorter when contracted, thickening in the middle. The contraction of a muscle makes it pull upon the bone to which it is attached, thereby causing it to move. The contraction of a muscle as a whole is brought about by combined contractions of all the muscle fibers. The motor neurons are attached to the individual muscle cells by means of motor *end plates*.

The all-or-none law holds for muscle fibers as it does for nerve fibers, in that a given muscle fiber contracts to its fullest extent or not at all. Thus the strength of contraction in any muscle is determined by the *number* of fibers excited. With only a few exceptions, such as the knee-jerk, the motor impulses reaching the muscle come in volleys. The muscle fibers do not have time to relax entirely after one impulse before the onset of another, so that the muscle contracts by a series of waves or twitches. Fig. 19 shows a typical record of sustained muscle contraction, the slight notches in the curve representing individual twitches in the muscle for each volley of impulses. The work of the muscle as a whole consists of a fusion of a vast number of these single twitches. The total response of the muscle is the entire movement from point *A* to point *B* in the figure.

As is to be expected, a muscle gradually *fatigues* to sustained

contraction. The evidence of fatigue in the individual muscle twitches can be seen by the gradual decrease in the extent of these twitches. After the individual muscle fibers have about reached their limit of contractibility, the whole muscular response weakens fairly rapidly (see the line from *X* to *B* in Fig. 19). The onset of fatigue varies greatly for different muscle groups, the finer and smaller muscles tiring more rap-

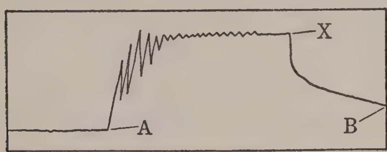


FIG. 19. A Muscle Contraction.

A record of the amount of contraction of a continuously stimulated muscle. *A* to *B* represents the total response of the muscle. Immediately after *A*, the muscle contracts by individual twitches. As these contractions become fatigued, the entire muscle effort weakens, as shown from *X* to *B*.

idly than the larger ones. This can be easily demonstrated by repeatedly moving the index finger of one hand and at the same time moving all of the fingers of the other hand. The gross movement can be kept up much longer than the simple one.

The Smooth Muscles. The smooth muscles are found chiefly in the viscera and in the arteries and veins. The smooth muscle tissue is composed of elongated spindle-shaped cells, each with a single nucleus and fine fibrils which run lengthwise throughout the cell. These muscles are supplied with motor nerves from the autonomic nervous system, and hence, unlike the striped muscles, are not directly under voluntary control. They are concerned primarily with the processes of digestion, excretion, and blood circulation.

Smooth muscles react much more slowly to stimulation than do the striped muscles. Groups of these muscles are constantly in operation while maintaining heart beat and respiration. Their contraction and relaxation produce the constriction and

dilation of the blood vessels. Constriction of these muscles serves to increase blood pressure, while relaxation decreases it.

The Glands. All glands of the body may be classified in accordance with the nature of the discharge of their chemical secretions. Those glands that have an external outlet, and consequently discharge their secretions either on the surface of the body or into some body cavity, are classified as *duct* glands. Those glands that have no external outlet, but discharge their secretions either directly or indirectly into the blood stream, are classified as *ductless* or *endocrine* glands. A few glands of the body pour out both external and internal secretions. Some of the principal glands of the body may be listed as follows:

Duct	*Ductless*
Salivary	Thyroid
Gastric	Parathyroid
Intestinal	Adrenal
Liver	Pituitary
Pancreas	Islands of Langerhans
Kidney	Sex
Sweat	Liver
Sebaceous	
Tear	
Reproductive	

The Duct Glands. The duct glands, like the smooth muscles, are concerned with essential processes of bodily maintenance. The salivary glands help to dissolve food substances placed in the mouth. The gastric and intestinal glands, along with the liver, function in the processes of digestion. The kidneys, and the sweat and sebaceous, or oily, glands, all serve to remove waste products from the body. The tear glands supply the lubricating liquid of the eye.

The Endocrine Glands. The endocrine, or ductless, glands pour their secretions either directly or indirectly into the blood stream, where they are carried to all parts of the body. The endocrine secretions are of two kinds: (1) those substances

which exert an excitatory influence on behavior, called *hormones*; (2) those that have an inhibitory effect on behavior, called *chalones*, or inhibitory hormones, which act to "slacken up" bodily activity. Normal bodily activity is determined largely by these inhibitory glandular functions.

The influence of the endocrine glands on human behavior is of great importance, but at the present time there is no complete picture of what they do. Not only have the various glands a specific bodily function, but the activity of any one gland has an effect on the others. The precise nature of this mutual effect is not entirely known. However, a brief description of the known functions of the several ductless glands can be given.

The *thyroid gland* lies just below the Adam's apple. It secretes a powerful hormone called thyroxin. If there is an *undersecretion* of the thyroid gland in the child, bodily growth is arrested, the reproductive organs fail to develop, and mental growth is greatly retarded. This condition is known as cretinism. In adults, a deficient thyroid secretion, or a complete loss of it, produces a dry skin, brittle falling hair, increased weight, and general inactivity. Such a person is frequently emotionally depressed, lacks interest in things around him, and is retarded in his thinking. If the gland *oversecretes*, it causes fast heart action, general "nervousness," irritability, and a number of other similar symptoms.

The *parathyroid glands* consist of four small bodies about the size of peas which lie in the thyroid. So far as is known, they have nothing to do with the activity of the thyroid. A malfunctioning of these glands causes muscular tremors, cramps, spasms, and often maniacal excitement. The complete removal of the parathyroids will cause death.

The *adrenal glands* are above and in contact with the kidneys. Each adrenal gland has two different structures called the cortex, or outer part, and the medulla, or central portion. The adrenal cortex secretes a hormone, "cortin," which has influence on all body cells. When the cortex fails to function the

individual becomes restless and irritable, and shows general bodily fatigue. There is some indication that the adrenal cortex is closely associated with the activity of the sex glands. The secretion of the adrenal medulla is called "adrenin" or "epinephrin," and plays a great part in emotional excitement.

The *pituitary gland* lies underneath the brain. It is divided essentially into a posterior and anterior lobe, each part having several functions. A hormone from the anterior lobe promotes the growth of the bones and bodily tissues. Oversecretion of this hormone results in gigantism, or excessive bodily growth. Other pituitary hormones exercise a stimulating effect upon the development of the sex glands and the related secondary characteristics, on the functions of the thyroid gland, and on the fat, carbohydrate and water metabolism of the body.

The *pancreas* is a duct gland that secretes enzymes which aid the processes of digestion. The *Islands of Langerhans*, which, in human beings, are embedded in the pancreas, produce *insulin*, a hormone concerned in the utilization of carbohydrates by the body tissues. A lack of insulin in the body causes diabetes.

The *reproductive* and *sex glands* have long been known to have both a duct and a ductless function. The external discharge of these glands enables the processes of procreation to be carried out. The endocrine function brings about a development of secondary sexual characteristics, such as the distribution of hair on the body and change in voice. Removal of the sex glands in the male during youth results in abnormalities such as a high-pitched voice, a beardless face, and a lack of sex aggressiveness. Removal of the ovaries in the female often causes tendencies toward masculinity.

The *liver* is important both as a duct gland and as an endocrine gland. Its endocrine functions include the transformation of waste products in the blood, and the regulation of the sugar content of the blood.

The *pineal body*, located in the head near the brain, and the *thymus*, located in the chest, are sometimes considered as en-

docrine glands, but the evidence is uncertain. Both of these organs function most actively in childhood and tend to atrophy after puberty.

The Neuromusculature

The combined system of receptors, sensory conductors, nerve centers, motor conductors, and effectors is called the *neuromusculature.* The complexity of the adjustments which an organism can make to its environment depends upon the degree to which its neuromuscular system is developed. The farther the animal scale is ascended, the more highly integrated the neuromuscular system becomes. The highest levels of adjustment mechanisms are found in man. However, in the human, the complexity of both the structure and the function of the neuromusculature differs from individual to individual. This accounts in large measure for the great differences in behavior and ability found among human beings.

Chapter IV

THE BEGINNINGS OF BEHAVIOR

The Genetic Approach

The best approach to an understanding of the behavior of the adult human being is to trace the course of development through which it is evolved. What behavior *is*, is revealed by the way in which it *grows*. This method of study is known as the *genetic approach*, and is widely used in the biological sciences.

The mammalian organism begins to behave soon after it becomes alive; this occurs some time before it is born. Individual life has its beginning when the female germ cell (ovum) is fertilized by the male sperm. This single fertilized cell divides into many cells, which gradually assume specialized forms and functions. In the earlier stage of development the organism is called an *embryo*. The embryonic period lasts until about the second month of prenatal life, by which time the human organism has taken on a characteristically human form (Fig. 20). During the remainder of the period of prenatal growth the organism is called a *fetus*. The fetal period is the second stage of development and lasts until birth. The first movements occur at about the beginning of the fetal period, eight or nine weeks after fertilization. It is at this point in life that behavior may be said to begin.

General Features of Early Development

The development of behavior is an orderly process. Investigations of fetuses of a large number of species, including salamanders, chickens, rats, guinea pigs, cats, and humans, have

revealed certain features that are common to all development. Some of the results of researches on lower vertebrates clearly illustrate these generalizations.

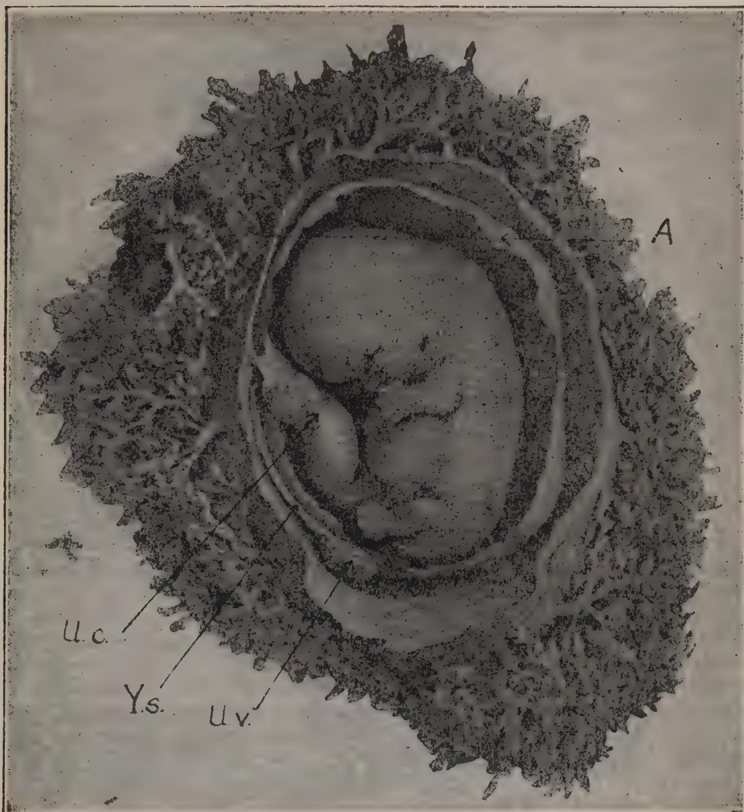


FIG. 20. Human Fetus.

The fetal period of development begins about two months after fertilization. The figure is an enlarged view of a fetus about 19 mm. (¾ inch) long, at a fertilization age of 7 to 8 weeks. (From H. E. Jordan and J. E. Kindred, *A Textbook of Embryology,* Appleton-Century.)

Developmental Sequences. The researches of Coghill on the early developmental stages of the salamander are classic. In the development of the swimming behavior of this little amphibian, it is observed that the first movement is a bend

ing of the head to the left or right. At a somewhat later stage of development this bending movement progresses along the entire animal (Fig. 21). In a slightly older animal, a second movement in the opposite direction may start before the first movement has reached the tail. This gives the "S-reaction,"

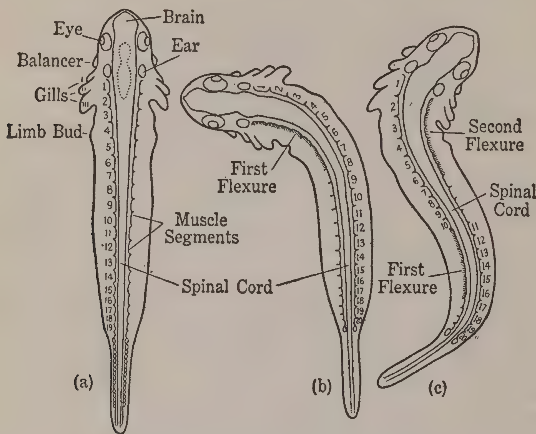


FIG. 21. The Development of Swimming Movements in Amblystoma.

From the resting position (a), the salamander begins its swimming movement by flexing the head to the left (b), and then to the right, while the first flexion passes toward the tail as a rhythmic wave down the bodily musculature. The result is the S-shape reaction (c). The movements at first are relatively slow, but they increase in speed as the animal grows older. When performed rapidly this movement becomes the typical swimming response of the salamander. This early behavior is a general bodily movement of the whole organism. (From G. E. Coghill, *Anatomy and the Problem of Behavior.* By permission of the Cambridge University Press, publishers.)

which is performed only slowly at first. In time, S-reactions are made rapidly and successively, resulting in swimming. In this reaction the little salamander uses all the musculature that it possesses, which consists of two lines of muscle segments, one on each side of the vertebral column. Its neuromusculature acts as an *integrated whole* from the very beginning.

As the salamander continues its growth it develops limbs. At first the legs move only with the trunk, and have no independent motion of their own. The leg movements are initially

but a part of the total behavior pattern. This is true of both the usual walking movements of the animal and of the responses it makes to specific external stimulation, such as prodding it on the leg, head, or trunk. If the foot is touched by a stick, the leg will not move independently, but the whole body will respond to the stimulation. Even in the early stages of walking, the four limbs are integrated with the movement of the trunk. The hind limbs do not move synchronously with the fore limbs, but lag behind them until the wave of movement down the body reaches their region.

It is out of this original total pattern of behavior that those local reflexes gradually arise by which each part of the body can be moved separately without involving any other part. In earlier stages the limb moves as a whole, then a movement at the knee becomes possible, and finally the movements of the ankle and toes obtain their independence. Local movements, then, are secondary, in that they emerge from the total bodily reaction after the neuromusculature has matured.

Developmental sequences of the same general nature are observed in all fetuses, including those of higher mammals as well as those of the lower vertebrates. The fetus of the cat, for example, moves its whole body at first, and only later shows independent movements of the limbs. The fore limbs precede the hind limbs in acquiring independence of action. The grosser movements appear first; the separate movements of the knees, ankles, and toes develop at later stages of growth.

Development from General to Specific Movement. The most significant generalization concerning the growth of behavior is that reactions follow a sequence of development from *general to specific*. At the outset, all organisms behave with primarily integrated and unified reactions. As the neuromusculature matures, the total bodily reactions become subdivided into specific differentiated responses. These specific or local movements are reflex in character. Specific reflex responses are therefore secondary types of behavior that develop later than the primary whole-organism behavior. Reflexes are thus

not the original units out of which behavior is built, but are themselves the products of the subdivision of a primarily integrated activity.

Anterior-posterior Sequence. Several other important laws may also be noted in the development of very young organisms. One is the *anterior-posterior sequence*; that is, development proceeds from the head toward the tail. The first movements of all fetuses are observed at the head end. The earliest areas that are sensitive to stimulation are the face and neck. In the development of individualized locomotion also, the forelegs attain some degree of independent movement prior to the hind legs.

The anterior-posterior sequence is an indication of the course of development of the neuromusculature. The nervous system becomes differentiated from the head downward, and specific reflexes are therefore first present in the regions controlled from the brain stem and the upper part of the cord. The muscles also mature earlier in the head end of the animal.

Central-peripheral Sequence. Development also progresses from more central to more outlying parts of the organism. As was described in connection with the salamander, first the whole leg, then the knee, next the ankle, and finally the toes become capable of independent movement. The parts that are nearer the bodily axis mature first, and the more peripheral members develop later. This generalization applies to postnatal as well as prenatal development.

The Effect of Stimulation on Development. Although the course of development is orderly, it is not determined entirely by inner nature or heredity, even in the prenatal stages, but is greatly influenced by stimulation from other movements. Many responses become differentiated by the "practice" that they receive during the prenatal period.[1]

[1] The student should clearly differentiate between fact and superstition here. There is an ignorant and unsupported belief that the experiences of a mother may "mark" the unborn child, or that the child's characteristics can be influenced by what the mother thinks or desires during pregnancy. The present section refers to the mechanical or neural influence of one movement of the fetus upon other movements.

The effects of stimulation upon development are well illustrated by the experiments of Kuo on the chick. By making a part of the shell transparent, this investigator was enabled to observe the continuous development of behavior during the period of incubation. Studying several thousand chicks in this manner, he saw all the stages of the developmental sequence of the chick embryo. The data he obtained supply further evidence that early development follows a *general-to-specific* sequence. The early movements in the egg form the elements out of which every later response of the adult chicken is built. The beating of the heart leads to a general rhythmic vibration which starts the head into passive mechanical movement. This passive movement soon develops into an active movement. The head begins to bob up and down, a movement which later enables the chick to peck itself out of the egg shell. The amnion, or sac, in which the embryo lies, contains true muscle fibers, and is at one period of development in an almost continuous state of rhythmic contraction. These contractions activate movements of the chick which are significant in the development of other later movements.

Thus, the experiences or stimulations of the fetus influence its development before birth, just as the experiences of an individual after birth affect his conduct in later life. This concept breaks down the barrier between "growth" and "learning," and between "native" and "acquired" characteristics. The two are only different aspects of the same essential process of development.

Prenatal Development of Human Behavior

The fetal development of human behavior follows the same general principles that operate in the other mammals. The key to adult human behavior, then, lies in a study of the behavior of the unborn child (prenatal) and of the infant after birth (postnatal).

Behavior of the Fetus. Although the heart beat of the human organism begins during the third prenatal week, a general bodily movement appears only after eight or nine

weeks of development. Minkowski, Hooker, and other investigators have shown that a general activity of the whole fetus appears first, followed by more specific local movements which become more frequent and vigorous as the fetus grows older. Behavior develops in close relationship with the growth of the nervous system. There is some reason to believe that behavior becomes more and more specific as the medullated nerve fibers begin to grow their protective sheaths. The growth of this "insulation" on the fibers permits them to act more independently, with the result that the nerve discharges do not spread generally throughout the nervous system, but are confined to more specific pathways.

Behavior Development and Physical Growth. The physical growth of the human fetus follows the law of anterior-posterior

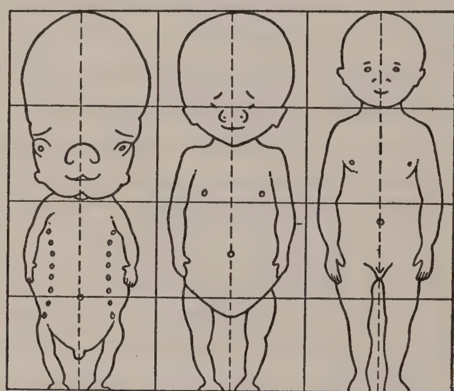


FIG. 22. Changes in Body Proportions During Fetal Life.

As the individual grows, the head matures earliest; hence it comprises a larger proportion of the entire body size during the earlier stages than during the later stages of development. (Modified after Hess; from L. Carmichael, in *Handbook of Child Psychology*, Clark University Press.)

development, like that of other animals. The head regions are more precocious in their growth than are the lower regions of the body. In the second month of prenatal life, the head constitutes half of the total body, and becomes proportionally smaller and rounder as age increases (Fig. 22). The various

sensory and motor functions appear first in the head region of the fetus, and progressively pass to the regions farther and farther removed from the head. The development of behavior parallels this physical growth of structures. The first body movements appear in the upper regions of the trunk near the head, and later on spread gradually downward and outward to the limbs. This development from a general reaction of the body as a whole to independent local movements of the arms and legs and then of the fingers and toes corresponds to the growth of the nervous system. The spinal cord and brain appear first, and are followed by the cranial and spinal nerves which serve as the more local neural pathways. The growth of the brain is in advance of the growth of the remainder of the nervous system.

Although local reflexes appear in the later stages of prenatal life, a complete individuation of local movements does not appear until several months after birth. The general-to-specific sequence of behavior development which begins in the fetal period continues into the early postnatal life of the infant. As far as the natural maturation or growth of the organism is concerned, birth does not mark any radical change. It only introduces a radical change in the physical environment and adds a social environment, but these changes do not greatly affect the continuous processes of behavior development.

The Behavior of the Newborn Infant

Early Behavior Patterns. Many lower animals have well-coordinated behavior at birth, while others, including the human newborn, are quite helpless. But this helplessness of the newborn infant is not an indication that its first behavior responses are just a mass of uncoordinated movements. A detailed analysis of motion pictures of infants' responses taken immediately after birth and each day thereafter through the tenth day, shows the presence of a number of typical patterns of behavior. These reactions are not provoked by specific forms of external stimulation, such as pinching the skin or

sounding loud noises near the infant. They are elicited chiefly by *internal stimulation* arising from the infant's own visceral organs and muscles.

Typical patterns of internally stimulated early behavior include crying, stretching, sneezing, mouthing, yawning, opening the mouth, chewing, sucking, and smiling. Descriptions of these responses show that they are divided into separate and distinct "patterns," each characteristically different from every other. A description of several of these typical early patterns of response makes it evident that Coghill's principle of development from general-to-specific behavior applies to the newborn, for it shows that although the responses are not one total pattern of behavior, each of the several different response patterns involves *total bodily reactions*.

Crying. In crying, the mouth takes on a four-cornered box shape appearance. The eyes are usually but not always closed when the cry has reached its height. The amount of limb movement varies with the intensity of the cry. In intense crying the arms are moved up and down rapidly and the legs are kicked violently. When the arms and legs are not moved they are always held tense, showing much muscular exertion. The infant thus cries "all over," all the skeletal muscles are tensed, the nose is pulled upward, and the face is wrinkled. Infant cries always have a slow and gradual termination as opposed to the rapid ending found in some other reactions.

Stretching. In stretching, the mouth is always closed tightly, and the eyes are usually closed. The limbs are held rigid. The infant often rears up on the back of the head, arching the back. The termination of a stretch is somewhat drawn out, the infant appearing to be very much relaxed after this general bodily movement.

Sneezing. The eyes are always closed on the inspiration of air into the lungs and remain that way until expiration of the sneeze. In strong sneezes the arms are jerked slightly upward and inward, the legs being flexed with a bend at the knees. The sneeze ends immediately after expiration.

Mouthing. The feature that distinguishes "mouthing" from "opening the mouth" is the protrusion of the tongue from the mouth against and across the lower lip. The limbs are relaxed and never move with any force. This general bodily relaxation shows that even this simple form of response is body-wide.

Yawning. Yawning is the only reaction where the newborn opens the mouth vertically. The limbs are relaxed, and the nose is always pulled up. Yawning begins slowly and ends abruptly.

Opening the Mouth. This response differs from the yawn in that the mouth opens horizontally, never vertically (this is obviously not true of older children). The limbs are relaxed.

Chewing. Chewing is distinguished from other mouth reactions by an up and down movement of the lower jaw, with no accompanying tongue play or lip reaction as found in sucking. There is a general bodily relaxation accompanying chewing.

Sucking. The essential features in spontaneous sucking are the protruding of the tongue beyond the lips in a "trough" shape, and a rhythmic motion of the lower jaw. The limbs are relaxed.

Smiling. The essential and peculiar factor in the smile is the retraction of the corners of the mouth upward. Smiling is always accompanied by a complete state of bodily relaxation.

Other Reactions. In addition to the above "patterned" responses of the newborn there are certain isolated limb movements. The movement of an arm or leg may be in any possible direction, but such movements are never as vigorous as those wherein the total organism is brought into play. Rubbing the face occurs frequently. Vomiting and hiccoughing were observed, these reflexes having already become differentiated out of a general bodily response.

From these descriptions it may be seen that the responses of the newborn may be divided into groups with respect to the rôle played by the limbs. Thus, in intense crying, sneezing, and stretching, the legs and arms are vigorously involved, the mode of involvement being peculiar to each response. In the case of facial response, on the other hand, the legs and arms are either totally inactive, or else moving with slight force. This indicates that the newborn's spontaneous behavior organization is body-wide, that the responses are *total bodily responses.*

Reflex Behavior of the Newborn Infant. A further study of the behavior of the newborn shows a partial development of certain isolated responses made to *external stimulations.* When a certain sense receptor is activated directly there follows a characteristic motor response to the particular stimulation. This is reflex behavior. The more typical of these reflexes

include the sucking response, the grasping and plantar reflexes, and a variety of postural reflexes. Many other forms of reflex behavior do not appear until months after birth. These typical reflex responses are originally only partially individuated, but become more specific as the infant continues to mature.

The Sucking Response. A stimulation of the reflex zone around the mouth and on the cheek of the newborn will arouse a sucking response similar to the internally stimulated sucking response already described. If the lips, or the region above or below the lips, or even the cheek, are touched lightly with the finger a typical sucking reflex is often noticed. Sucking may also be elicited by placing a sweet sugar solution in the mouth. Pratt, Nelson, and Sun have shown that, with increasing age, sucking movements to cheek stimulation diminish in frequency. Although the sucking response is fairly specific from the start, the general area of stimulation gradually narrows down to a point where a stimulation of the cheek will no longer elicit the response. The reflex area has become specifically localized to the regions of the lips. This clearly shows the general sequence of development not only for the response, but for the area of stimulation as well.

The Grasping Reflex. When the palmar surface of the hand is stimulated by some form of contact there is a flexion of the fingers. This is the grasping reflex, or, as it is sometimes called, the *palmar response.* The grasping reflex in many infants is so strong that they can support their entire weight for a few minutes by holding on to a stick placed in their hands. In newborn monkeys this reflex is much stronger, a monkey being able to support itself for many minutes by grasping an object with only one hand. In human infants the grasping reflex disappears after about the sixth month. When this early involuntary response becomes extinct it is gradually replaced by a voluntary type of grasping. This fact indicates how voluntary behavior, which is a higher form of behavior response, develops gradually as the neuromusculature grows to the point when the higher brain centers

become associated with what was at one time a lower type of reflex response.

The Plantar Reflex. The plantar reflex, or as it is often called in infants, the *Babinski reflex*, is of great significance in the study of developmental behavior. When the sole of the newborn infant's foot is stimulated with a blunt object the response that follows is one of a disorganized *extension* of the toes. The big toe extends outward and upward while the other toes spread out in a fanlike shape. This characteristic toe response is found in all normal newborn infants. It is named after Babinski, who first discovered a similar plantar response in adults who had lesions in the nerve fibers coming from the motor area of the brain. The Babinski reflex in the newborn is caused by an ~~incomplete growth of~~ the myelin sheath ~~on these~~ motor nerve fibers. This nerve fiber myelinization becomes complete at about six months after birth, causing the response to change to one of toe flexion when the sole of the foot is stimulated. In its earlier stage of development the Babinski response is generalized both as to skin receptor areas and the effector segments activated. With a progressive development of the neuromusculature there comes the specific flexion response. A flexion of the toes when there is a stimulation of the sole of the foot is the characteristic normal response in adults. Therefore, the Babinski reflex is found only in newborn infants and in adults whose nervous systems have been damaged. The flexion response lasts normally throughout life, and, like the grasping reflex, soon becomes a part of the organism's voluntary behavior.

Sensory Capacities of the Newborn Infant. There is some development of the child's sense organs before birth. Studies show that at birth the newborn can make visual discriminations between lights of different brightnesses. It is doubtful if young infants see colors as adults do, but a recent research shows that babies two weeks of age will follow a colored spot with the eyes when it is moved on a background of equal brightness but different color. Sensitivity to sound stimuli is

quite noticeable a few days after birth, particularly to tones of a fairly high pitch. Immediately at birth most infants do not respond to sound stimuli because of a mucous secretion in the middle ear. As this secretion is cleared, auditory sensitivity becomes quite apparent. Sensitivity to taste and smell is also present, as evidenced by studies of the ways infants react to food substances. Babies also show marked responses to changes in temperature. They react quite differently when given warm and cold milk. There is much evidence that the temperature sense is extremely well developed at birth. The organic senses of hunger and thirst seem to function well in the newborn. Pain sensitivity is present at birth and gradually increases with age. Senses of movement and balance are obviously present at an early age, since they are directly connected with the postural responses.

Whereas it is true that the sense organs function actively at birth, it is doubtful if they provide the infant with information about his environment that is comparable to the sensory experiences of adults. In this early stage of development the sense organs function chiefly as receptors for reflex responses. Gradually the receptors begin to serve the function of making the child conscious of the world about him. As more and more experience is accumulated, the things seen, heard, and felt take on additional meaning. Thus the sense receptors not only come to serve as parts of the many reflex mechanisms, but arouse all varieties of conscious experience which are so necessary in enabling the individual to adjust to his changing environment.

Postnatal Development

The general features of development found in the fetus and the newborn are continued in the child. Some illustrations of this fact will be given from the development of postural control, of motor coordination, locomotion, and language.

Postural Development. The newborn infant is capable of making several types of postural reflexes, including varying

degrees of flexion of the arms at the elbows and of the legs at the knees. One of the most typical reactions of this sort is the so-called "startle response" which results from the sudden loss of support. If an infant is held in the hands face up, so that the arms and legs are free to move, any sudden drop will cause a quick outward extension of both the arms and legs. This startle response is present at birth, and there are indications that it lasts throughout life. When an adult sitting relaxed in a chair is suddenly tilted backward, his arms and legs fly outward much in the same manner.

Shirley has found that the development of infant behavior which results in the ability to maintain an upright posture begins at the head and proceeds down the neck and trunk to the legs. At birth the baby has no control over its head and neck muscles. When it is held upright it cuddles on the nurse's bosom and rests its head on her shoulder. This behavior continues until the head and neck muscles are under control, so that the nurse's hands need be placed only at the nape of the neck, later at the shoulder blades, still later in the thoracic and lumbar regions, and finally only under its buttocks. The varying degrees of support necessary to keep the baby sitting upright on the lap also illustrate the principle that the infant begins to assume an erect posture at the head end, and gradually works downward. In order for the baby to sit alone the entire trunk must be under control. Thus the sequential development of the infant in his ability to maintain an upright position through postural reflexes follows the same law that governs anatomical growth. Behavior development parallels structural development, namely, from the head downward, and from the general to the specific.

Development of Motor Coordination. A noticeable advance in motor coordination occurs during the first months following birth. The patterns of general activity are replaced by more adaptive movements of local parts of the body. Although local reflex movements do not become highly individuated until several years of age, the growing infant shows an ever-

progressing motor coordination as specific reflex movements gradually develop.

An investigation that shows how specific motor behavior develops from general behavior is the prehension experiment of Halverson. The infants were seated at a table and small wooden cubes were placed within their reach. The sight of the cubes was a sufficient stimulus to bring about the grasping response. Studies were made of the manner in which the infants reached for the cubes at different age levels. The infant

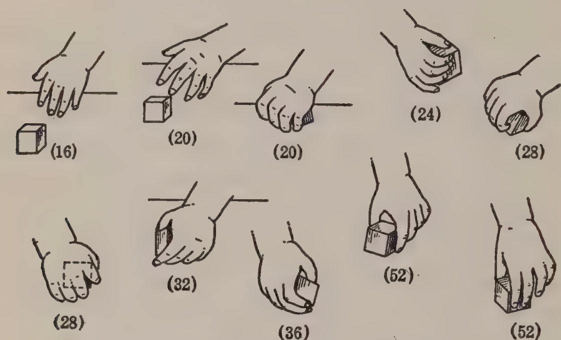


FIG. 23. The Development of Prehension.

The sequence from general to specific behavior is seen in the development of prehension or grasping. The ages at which the various types of prehension typically occur are given in weeks. (Modified after H. M. Halverson, *Genet. Psychol. Monog.,* vol. 10, nos. 2-3, 1931.)

of 16 weeks of age gazed at the cubes but failed to grasp them, although moving the body somewhat toward them. Four weeks later the child grasped the cubes, but only after an effort involving a general looping movement in which the entire upper portion of the body participated. Each cube was scooped in through a roundabout movement of the shoulder and upper arm, and grasped in the palm of the hand. Later, at approximately 28 weeks, the child reached for the cubes somewhat less awkwardly, but with a rather crude manipulation of the fingers, the thumb not taking part in grasping. The arm movement had become sufficiently controlled so that on reaching for the cube the child did not bring the general shoulder movement into play. A further advance was seen at

32 weeks when, though still continuing to rest his hand on the table, the child grasped the cube with only the thumb and the first two fingers. At 52 weeks of age he could grasp the cube with the thumb and the two forefingers without resting the hand on the table. Fig. 23 shows this sequence.

The Development of Locomotion. Shirley's studies of twenty-five babies during the two years after birth show the progress that is made as reflex behavior becomes more and

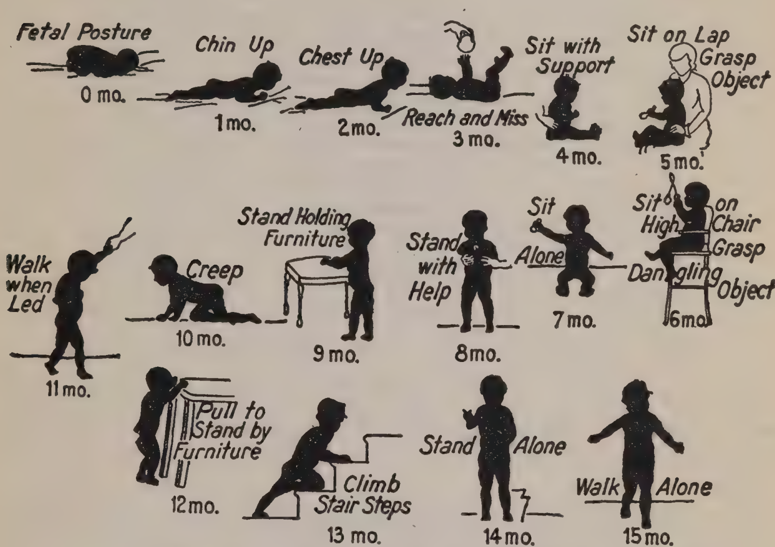


FIG. 24. The Development of Posture and Locomotion in Infants.

The sequences of development from general-to-specific and from head-to-legs can be seen clearly in the acquisition of habits of walking. (From M. M. Shirley, *The First Two Years,* University of Minnesota Press.)

more definite. The development of the coordinated locomotor behavior which leads to walking comes about gradually, as indicated by the drawings of Fig. 24. In the first month the infant can only hold up the chin for brief periods of time. In the second month the chest can be raised. At four months of age the infant can sit in an upright position only with support. In the seventh month the normal baby can sit alone; this is soon followed by the ability to stand with help. Walk-

ing with some aid follows after the period of crawling has been passed. At fourteen months of age the average baby can stand alone, and at fifteen months can walk around by himself. From this time on there is further improvement in motor coordination. Fig. 25 gives a graphic illustration of the several stages of this locomotor development.

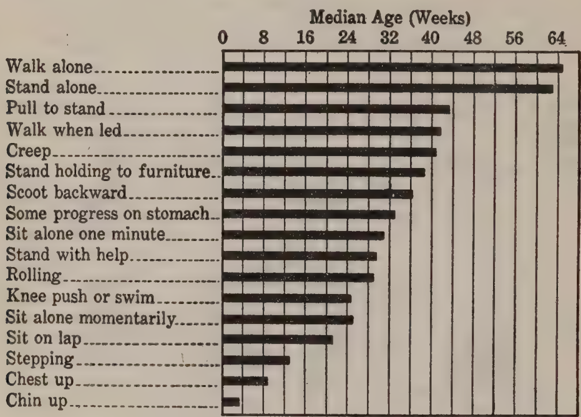


FIG. 25. Stages of Locomotor Development.

The graph shows the median age (in weeks) at which the various response patterns were first observed. (From M. M. Shirley, *The First Two Years,* University of Minnesota Press.)

Development of Speech and Language. The mechanisms of vocal response are partially developed at birth, as is indicated by the "birth cry" of every newborn. This first cry enables the infant to start breathing. A few weeks after birth more differentiated cries may be observed. Some seem to be closely associated with discomfort, others appear to be just random utterances. Later the baby makes crowing and gurgling sounds that resemble certain vowels. As the vocal organs continue to develop, the sounds become more definite. Characteristic of these sounds are "ma-ma" and "da-da," which many parents interpret as "mama" and "daddy." However, such early "recognition" on the part of the infant is impossible. The sounds are just the easiest for him to make. Nevertheless,

the social factor of imitation soon becomes apparent. As the mother repeats "mamma" to the child, he gradually learns to associate the sound with mother. This step marks the beginning of the socialized response, *language*. Speech in itself is a sensory-motor reaction which becomes language when *meaning* becomes attached to words, that is, when words become symbols for objects and situations. First a single word is used to express or convey a whole meaning. Thus the small baby may say "milk" in order to obtain what he wants. Later he begins to express himself in phrases such as "all gone," and finally his language develops to the stage when ideas are conveyed by whole sentences. The greater the opportunity a growing child has to associate words with objects and situations the greater will be his language development.

Maturation—The Beginning of Learning

The previous sections of this chapter have been devoted to a discussion of how growth determines the progressive modification of behavior in the early life of the human organism. The term *maturation* has been used to describe the early stages of development where changes in behavior are correlated with observable *growth*. The term *learning* is most generally applied to the second phase of the developmental process, where a modification of behavior is correlated with observable stimulating *situations*. Thus, an infant first starts his walking behavior as a natural result of normal neuromuscular *maturation*; but with *practice* walking is improved. In both stages of development the end result is the same: a gradual modification of behavior. Behavior patterns change at the early levels of maturity without any specific practice effects. After various stages of maturity have been reached, behavior is further modified by practice. For this reason maturation and learning are simply two different phases of the same process. Maturation marks the beginning of the continuous process of behavior modification, or the beginning of the process more generally called learning.

Learning and Sequential Development. The process of learning after birth is clearly a continuation of the developmental modification of behavior. The newborn infant presents a group of general behavior patterns all of which have some general organization. The "spontaneous" responses of the newborn fall into "patterns" of behavior such as crying, sucking, sneezing, smiling, and the like. All these responses are total bodily reactions having certain behavior elements peculiar to each response. Thus, when the newborn cries, "he cries all over." There is a general activity which is characteristic of the cry, a general movement of the arms and legs accompanying the facial expression. When he smiles, "he smiles all over" because there is a general body relaxation peculiar to what is evidently a condition of satisfaction. As the infant develops, these general patterns become more specific. At the age of a few months the child no longer "cries all over." The general body activity is greatly decreased, and the crying reactions are now limited chiefly to the facial muscles.

Following this maturational development the effects of practice on further behavior modification become evident. The child learns to cry when he wants attention because a repetition of this response has brought desirable results. He learns to smile when smiled at, to cry when ugly faces are made at him. Thus he has learned to make different behavior responses to different types of social stimulation. Maturation makes the specific responses possible, while practice causes them to be associated with specific stimulating factors. Both maturation and practice are responsible for the progressive changes in behavior.

The general-to-specific sequence is characteristic of all growing organisms. It is not confined to the maturing infant, but continues even in adult life. When an adult makes adjustments to a new situation he goes through an early stage of generalized behavior which later develops into a well-defined and specific adjustment by the process of learning. When an individual first learns to drive an automobile, his reactions are

more or less vague and uncontrolled. He realizes that there are pedals to operate, gears to shift, and other things to do, but he has a hard time to do these things and still keep the machine out of the ditch. At first he is awkward; he must direct his attention to this and to that. Finally, after some practice and effort, each specific manipulation becomes a habit, and an adjustment to a new situation has been made. The following chapter will be devoted to a discussion of how adjustments are made to situations through the learning process.

Chapter V

LEARNED BEHAVIOR

The Nature and Varieties of Learning

The Meaning of Learning. One significant difference between the behavior of an adult and that of an infant is the more specific and adaptive nature of the adult's reactions, in contrast to the more diffuse and generalized movements of the infant. This is so because the adult has learned many useful habits that the infant still has to acquire. In the earlier stages of human development the modification of behavior is correlated largely with the natural growth of the neuromusculature. This phase of development, known as maturation, has been described in the preceding chapter. In the later stages of progress toward maturity, changes in behavior are brought about by the activities that the individual performs under the stimulating influence of the environment. The present chapter is devoted to an analysis of the conditions under which learning occurs.

The meaning of learning is made clear by examining an instance in which it has taken place. Here is a telegrapher who skillfully and rapidly translates language into the dots and dashes of his telegraph key, or deciphers the clicking of his receiving instrument. A year ago, perhaps, he could do none of these things. What are the changes in his behavior that show the effects of learning? He now reacts *specifically* to the dots and dashes as language, whereas formerly they were only noises that called forth no consistent response. As compared to those of the beginner, the expert's reactions are more *definite* and *uniform*. They are less variable, and the expert

makes fewer errors. Also, he shows a superior *organization* of his skill; he thinks of whole words at a time in terms of telegraphic code, whereas the beginner has to think letter by letter. Finally, the expert shows greater *speed* and a superior general *adjustment* to his task. A well-learned performance is specific, definite, uniform, organized, rapid, and, in general, adaptive.

Not all learned reactions result in desirable adjustments, however. Bad habits are learned as well as good ones, and are formed under much the same conditions. A child who has been attacked by a dog may fear all dogs thereafter. A fear of dogs has thus been learned through the influence of the stimulating environment. If all dogs were dangerous this would be a useful and adaptive habit; but since this is not so, the learned fear is unadjustive and unfortunate.

The permanence of learning, of course, depends upon persisting changes in the neuromusculature. Every reaction that an individual makes causes some slight change in his nervous system. Conduction pathways are modified in the process of learning so that some neural circuits become more likely to conduct and others less likely to do so. It is possible that these changes occur at the *synapses*, the points at which neurons come into contact. In this sense, the individual who has learned something is not quite the same organism that he was before. Maturation and learning, then, are alike in depending upon changes of the neuromusculature. They differ only in the means by which the changes are brought about.

Approaches to the Study of Learning. Psychology aims to find out, by means of experimental methods, the nature of the learning process and the conditions under which it will occur. Two principal experimental approaches to the problem of learning have been used. In one type of experiment, the subject is required to *discover* the solution of a problem, so that he learns to solve it more quickly when the same problem is presented again. The individual is free to try to solve it in any way that occurs to him; he is not given the answer. Learn-

ing progresses by the modification of the response that is made to the situation. At first the response is general, vague, and incorrect, while later it becomes more definite and skillful. This form of learning as a *response modification* is often known as "selective" learning, since the right movement has to be selected from among many possible responses. It is also called "trial and error" learning, since the process starts out in something of a hit-or-miss fashion. An infant learning to talk, a boy learning to ride a bicycle, and a student learning to solve an algebra problem are everyday illustrations of this process.

The second type of experiment has investigated the conditions under which the individual learns to make a previously established response to a new stimulus. A student of French learns to say "dog" when he sees *chien* in print. The new stimulus *chien,* has become capable of arousing the already established response of saying "dog." This form of learning proceeds by *stimulus substitution* and is called "associative" learning, since the stimulus and the response are said to have become associated or linked together. A child learning to fear dogs, a man learning the name of a new acquaintance, and a person learning a telephone number are examples of associative learning.

It is not possible to classify all examples of learning as either "selective" or "associative." Most of the complex acts of learning that occur in real life involve both response modification and stimulus substitution. Moreover, there are many resemblances between these two processes which a more detailed study will reveal. Selective and associative learning are not two "types" of learning, but are two approaches by which the entire learning process may be investigated and understood more clearly.

Selective Learning

The way in which individuals adjust to new situations has been described in Chapter II. It is fortunate that the adjust-

ment process is usually accompanied by learning. If man did not profit from his past experiences, and if every situation appeared to be a new one, the possibilities for effective behavior would be much reduced. It is important to examine the process of adjustment to determine why it leads to learning, and under what conditions it does so.

Learning by Trial and Error. It is instructive to watch the behavior of an animal or a person who meets a relatively new situation that demands an adjustment. Among the first

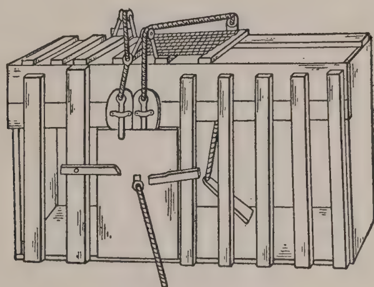


FIG. 26. A Puzzle Box.

This is a typical puzzle box used in the early experiments on selective learning. The animal was placed inside and the food incentive was placed outside. To escape from this difficult box, the animal had to depress a pedal, pull a loop of cord, and turn a latch. (From E. L. Thorndike, "Animal Intelligence," *Psychol. Rev. Monog. Sup.*, vol. 2, no. 4, 1898.)

systematic observations of this sort were those of E. L. Thorndike (1898) upon the behavior of cats which were made to escape from puzzle boxes (Fig. 26). Food was placed outside the box in full view of the hungry cat confined within. In order to reach the food the cat had to pull a string or step on a pedal or operate some other device that would open the latch. When first placed in the box the cat scratched and clawed at the bars or tried to squeeze through them. It struck at various parts of the box and engaged in vigorous and varied responses. In the course of this random activity the cat happened to pull the string that effected his release. This successful movement was present among the initial random fumblings, and the

animal came upon it quite accidentally at first. On repeated trials it was observed that the number of random movements decreased, until finally the successful response was made immediately when the cat was put in the box.

This pattern of behavior is often called *trial and error* learning. The animal's varied responses constitute the "trials," and the discarded useless movements are the "errors." The essential condition for trial and error learning is that the ani-

FIG. 27. Time Improvement in Puzzle Box Learning.

The time taken by a cat to escape from the box on successive trials is shown. At the left is a graph of the quick learning of a simple and easy box. At the right is a learning graph for the very difficult box shown in Fig. 26. (From E. L. Thorndike, "Animal Intelligence," *Psychol. Rev. Monog. Sup.*, vol. 2, no. 4, 1898.)

mal must engage in varied activity. If it merely tries the same response over and over again no progress will result. A certain amount of apparently useless activity often provides the condition that leads to the correct solution. The cat, for example, must discover that the first response of clawing at the bars is ineffective before it will try the less obvious movement of clawing at the string. The progress of learning can be represented graphically. Fig. 27 shows the course of improvement of the performance of a cat, represented in terms of the time taken to escape on successive trials.

Another type of problem that has been used extensively for

studying the nature of selective learning is the maze (Fig. 28). A hungry animal is placed at the entrance of a maze at the end of which there is food. It must find its way through the correct pathways and learn to avoid the "blind alleys" that lead only to obstruction. The course of learning in this case is not unlike that seen in the puzzle box situation. At first all alleys are entered quite by chance. During a sequence of trials

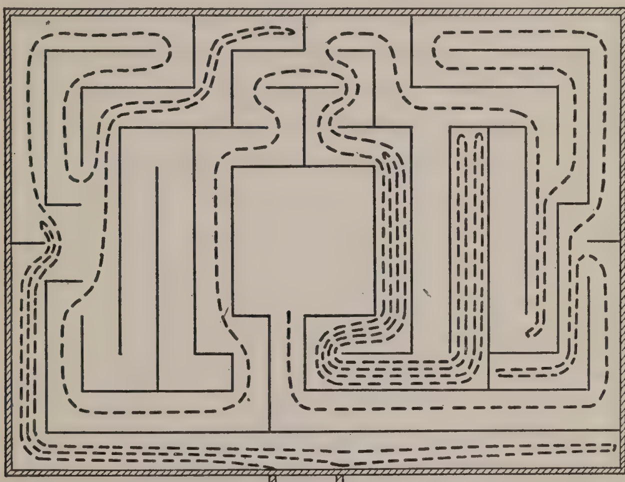


FIG. 28. The "Hampton Court" Maze.

This maze pattern was used in some of the first experiments on maze learning. The rat is placed in the entrance and has to find his way to the goal. The dotted line represents the path taken by a rat on the fourth trial. The rat took 4 min. 2 sec. to reach the goal and made 8 errors. (From V. C. Hicks, *J. Anim. Psychol.*, vol. 1, 1911.)

the animal comes to make the correct turns more surely and to avoid the wrong paths, until finally it learns to run through the maze rapidly without error. Mazes for investigating human learning can also be constructed by making the pattern more complicated, or by depriving the subject of some advantage, as by blindfolding him.

The Process of Selective Learning. There are four principal factors in trial and error learning which may be described as

a sequence. These are the *set* or motivation toward a goal, the *selection* of the correct response, the *elimination* of useless responses, and the *fixation* of the final learned act. An examination of these four steps will reveal the conditions essential to trial and error learning.

First, the learner must have a general *set, attitude* or *motive* toward the goal to be attained. Activity is essential to learning. If an old, contented, well-fed cat who is accustomed to confinement were placed in the puzzle box, no learning would occur because no activity would be aroused. Moreover, the possibilities of action must be determined by the problem at hand, and not merely represent any kind of random activity. The cat must be set to get out of the box, and not to scratch its ear or wash its paws. This set is determined by the external incentive, the dish of food, and by the cat's physiological condition of hunger. The activity in trial and error learning must be activity toward the goal; it is random only in the sense that the successful response has not yet been discovered.

The second and third steps of the learning process are intermingled and cannot be considered separately. These are the *selection* of the correct response and the *elimination* of the useless responses. As the individual solves the problem again and again, he is found to make the correct response more promptly and efficiently. He *selects* the right reaction from among the numerous and varied responses that were present in the earlier trials. Evidence indicates that a reaction is selected because it leads to a favorable end result. The "right" response in the puzzle box is the last one made, just before the animal escapes. It therefore leads directly to the completion of the activity in which the animal has been engaged, and to the satisfaction of the "set" or motive with which it attacked the problem. In other words, the selected responses are those that lead to the fulfillment of the adjustment.

The *elimination* of the unsuccessful acts takes place by the opposite process. Unsuccessful trial responses may be annoying, as when the cat bumps its nose against the bars, or they

may merely be actions that fail to secure adjustment, as when the animal vainly claws at the cage. Ordinarily, an animal will not repeat a useless and frustrating activity indefinitely. Therefore, the useless movements become eliminated, resulting in a greater precision in the performance as a whole.

A confirmation of the part played by the attainment of the goal in the selection and elimination of responses comes from

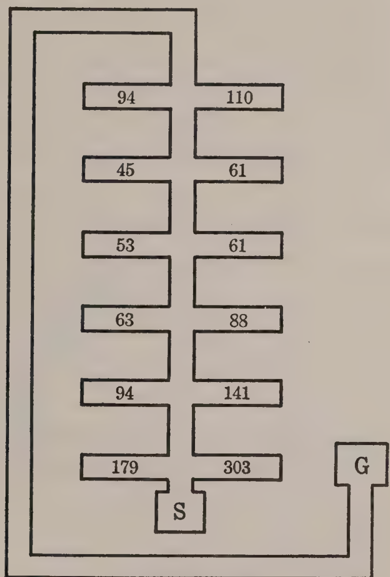


FIG. 29. Distribution of Errors in a Simple Maze.

The figure in each blind alley indicates how many times it was entered during a series of 1900 rat runs. More errors are made near the start (*S*) and progressively fewer in the blind alleys that are nearer the goal (*G*). An exception is found in the large number of errors in the last alleys, which are "goal anticipation errors." In this particular maze more errors are made to the right than to the left because of a general orientation toward the goal, which lies on that side. (B. von H. Gilmer, unpublished data.)

certain experiments in maze-learning. An animal first tends to eliminate errors that are nearest the goal; those more remote from the goal are harder to eliminate. Fig. 29 shows a simple maze that demonstrates this fact very clearly. The

blind alleys remote from the goal are entered more frequently, those near the goal less often. The animal, therefore, learns from the goal to make the last correct choice before the goal, and so on "backward" to the start of the maze. This fact has important implications for human learning. Something that is closely related to a goal will be learned quickly. A mechanically inclined boy may learn with ease the skills taught in the school shop, but he may have more trouble with mathematics, which seems to him less directly related to his interests, even though it may be more important from a long-range point of view. Persons learn what they want to learn more readily than that which is forced upon them. Elementary and secondary schools have recently given much attention to this important principle.

The fourth stage of trial and error learning consists of the *fixation* of the successful act. When the selected response has been repeated many times with a satisfactory result it becomes more prompt, more precise, and less variable. Often the result of fixation appears only after a lapse of time. If an act has been learned only to the point of one or two successful performances it may be forgotten readily. If it has been practiced further, the skill may be remembered for a longer time. Fixation depends upon repeated performance under conditions conducive to learning.

Slow and Quick Selective Learning. A great many acts of learning among human beings as well as among animals are performed by the laborious process that has been described. A solution is hit upon by accident and is learned gradually. In certain other situations, however, a much quicker process of selective learning has been observed. A person, or one of the higher animals, may arrive at a solution soon after the problem is presented, and with very few "useless" movements. This rapid selective learning seems to progress without much trial and error of the sort described previously.

The rapid type of selective learning was brought to attention by the German *Gestalt* school of psychologists. One typ-

ical observation, made by W. Köhler, will serve as an illustration. A chimpanzee, Sultan, was placed in a cage outside of which and beyond his reach lay a banana. Two bamboo sticks were put in the cage, one of larger diameter than the other.

FIG. 30. Sultan Making a Double Stick.

One of Köhler's apes solving the double-stick problem. This experiment illustrates the rapid type of selective learning. (From W. Köhler, *The Mentality of Apes,* Harcourt, Brace.)

Either rod was too short to reach the food. Sultan, who already had learned to draw food into the cage with one stick, first tried to reach the banana with one of the available bamboo rods. Since he discovered that the rod was too short, he soon abandoned these futile attempts. Next, he laid one rod on the ground and pushed it with the other one, until it touched the banana. Of course this procedure was ineffective,

but he was somewhat satisfied since he had "established contact" with the goal. This activity was repeated several times but was finally given up. Sultan then drew both sticks back into the box. A little later he picked them up and played carelessly with them. While doing this, he held one stick in each hand so that they lay in a straight line. Then he inserted the smaller rod into the hollow end of the larger one, making a continuous stick of adequate length (Fig. 30). *Immediately* he ran to the bars and drew in the banana with the combined rod. On the next day, Sultan was given the same problem, and began by pushing out one stick with the other, as before. After he had pushed one rod forward for a few seconds, however, he retrieved it, quickly put the two together, and drew in the reward with the double stick.

The behavior of Sultan, like that of human beings in many situations, offers a contrast to the random scramblings of the cat in the puzzle box. This difference is due in some degree to the nature of the problem that is presented, and in part to the nature of the organism. First, the problem is simple and the elements needed for its solution are all visible. In the puzzle box the cat could not see all the mechanism that effected its release, whereas the ape had all the materials clearly in sight. Second, apes are better learners than rats and cats. It is likely that the higher apes, like man, can use "mental" manipulation to some extent, as will be described later. However, cats can show quick learning if the problem is very simple. Thorndike found rapid improvement in escape from a box closed only by one simple latch. Other experiments show that even rats can combine two previously learned reactions into a new response that solves a problem. The rapid improvement that occurs with a minimum of overt trial and error is clearly a superior kind of learning, and is important for understanding many reactions of human beings.

Trial and Error in Human Learning. Human beings often employ trial and error, and of the crudest kind. It is not difficult to set up experiments to demonstrate this. One commonly

performed experiment is that of "mirror drawing" (Fig. 31) in which the subject has to trace a pattern he sees only in a mirror. Few persons solve this by reasoning about the conditions of the reversed image. Instead they strike out in one direction, find it to be wrong, and then try another. The average man whose automobile will not start shows similar behavior. He may continue ineffectively to push the starter button, or he may pull the throttle and choke randomly. A student solving a new problem in mathematics does not proceed directly to the correct answer, but may try a number of

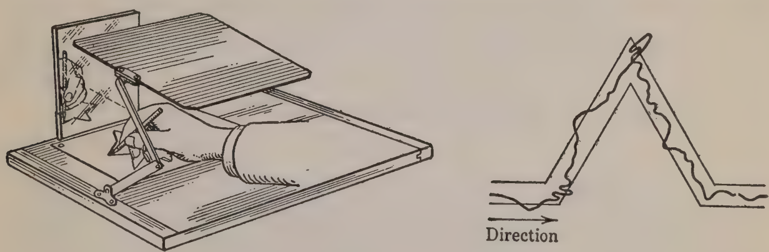


FIG. 31. Mirror Drawing.

At the left is a mirror-drawing apparatus. At the right is a part of a subject's first attempt to trace the star pattern. (Courtesy of C. H. Stoelting Co.)

approaches, finally arriving at a suitable one. Upon meeting a similar problem he makes fewer false starts; after further practice, he solves each such problem directly and rapidly. Broader life problems such as designing a house, choosing a career, or writing a book involve trial and error activity.

Along with the striking similarities between human and animal learning, there are also some significant differences. These are differences of degree, however, not absolute differences of type or kind. Human trial and error learning excels animal trial and error in two principal ways. First, man makes greater use of "symbolic" trial and error in addition to his motor trial and error, and second, he is more capable of profiting by past experience. In symbolic manipulation actions are represented by words, gestures, diagrams, images, or other symbols, instead of by more direct and obvious movements.

Whether trial and error proceeds as overt motor activity or as symbolic manipulation depends upon the particular situation and the experience of the individual who is attempting to solve it. In most instances of selective learning both processes operate. Consider the case of a scientist who desires to build an apparatus for use in research. He might proceed by throwing together a conglomeration of vacuum tubes, resistors, switches, and the like, and then seeing if the resulting instrument will by chance serve his purpose. But he has a better way. He studies the needs of his apparatus, talks it over with himself, uses diagrams, and makes calculations. He thus arrives at a solution of a large part of his problem before touching the actual materials. By this symbolic manipulation he can determine what plan is most promising, and proceed to follow it out in action with a gain in efficiency. In the final stages of the construction and regulation of the instrument, however, some motor trial and error will be used. Symbolic trial and error does not entirely replace overt muscular manipulation.

Man's superior ability to profit from his past experience enables him to narrow the range of his random activities so that the correct solution comes without too much irrelevant work. The degree of such benefit depends upon the similarity of the present problem to some other one that has been solved in the past. An individual skilled in algebra may solve a new problem in quadratics with little trial and error. But if the same person is unacquainted with logic, a problem in this field will call forth less definite responses. The benefit of past experience, therefore, is to restrict the range of attempted responses to those likely to succeed. The more complex forms of symbolic trial and error will be described more fully in later chapters on remembering and thinking.

Associative Learning

One of the oldest known principles of learning is that of association. "The burnt child dreads the fire" tells the story of the substitution of one stimulus for another because of

association. Everyday examples of association are very numerous. We "know" a person's name because it has been associated with his presence. After this learning has occurred, hearing the name will evoke certain responses as effectively as if the person were pointed out, pictured, or described. Association may affect very fundamental physiological reactions. The normal stimulus for a flow of saliva is the taste of food. But often the mouth will water at the mere sight of a luscious apple, or even upon hearing it described or thinking about it. This happens because the sight, description, or thought of an apple has often occurred together with its actual taste. Thus one situation is "substituted" for another to elicit some type of behavior.

The Conditioned Response. The factors essential to associative learning have been investigated by the *conditioned*

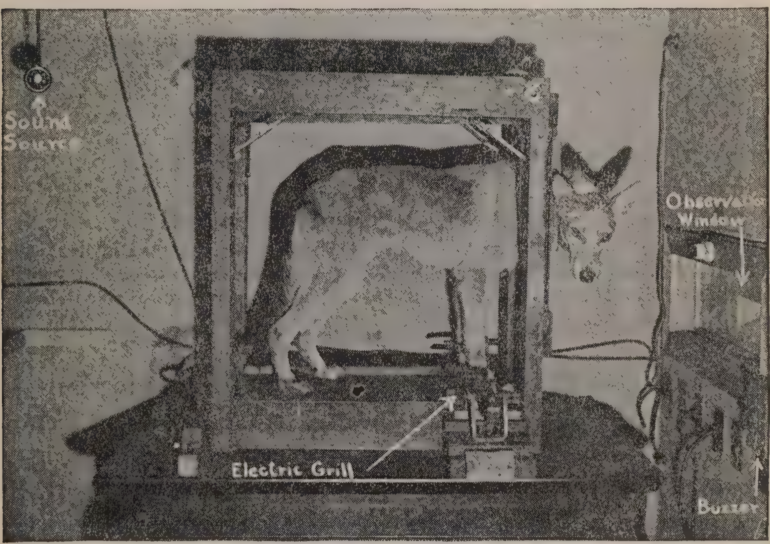


FIG. 32. Apparatus for Conditioning a Motor Response in Dogs.

The dog's right front foot rests on an electric grill that provides the natural or unconditioned stimulus, a shock. The response of lifting the foreleg causes the shock to cease. The conditioned stimulus, a sound, is given through the speaker seen in the upper left corner of the picture. Other stimuli may be used, such as the buzzer. The experimenter controls the stimulating situations and records the responses from the observation room at the right. (Courtesy of Dr. E. A. Culler.)

response technique. Fig. 32 shows a typical experimental arrangement for the establishment of conditioned responses. In a sound-proof room that excludes all unwanted stimuli, a dog is strapped comfortably in the apparatus. An electric shock is administered to his fore leg, causing a withdrawal of the paw. Just before the shock is given, a tone is sounded from a nearby telephone receiver. After this combined stimulation has been repeated a number of times, the dog will lift his foot upon hearing the sound, before the shock comes. The dog is said to have been conditioned to make the withdrawal movement for the sound stimulus. The tone is now called a *conditioned stimulus*, and the response to it is a *conditioned response.*

What happens in a process of conditioning is shown in Fig. 33. A stimulus that did not "naturally" evoke the response has been conditioned to bring it about. In other words, an

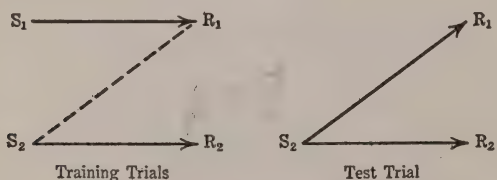


FIG. 33. The Conditioned Response.

During the *training trials* the shock (S_1) evokes the response of foot withdrawal (R_1), and simultaneously the tone (S_2) evokes the response of hearing. After repeated training, on a *test trial*, the tone alone evokes the foot-withdrawal response.

originally ineffective stimulus has been made effective by associating it with the naturally effective stimulus. The essential requirement for conditioning is that the two stimuli shall *occur together*. They are presented simultaneously, or else with the new stimulus a little prior to the original one. Presenting the older stimulus (shock) before the new one (tone) usually results in no learning, or in a very slow and weak conditioning. This is analogous to rewarding a child before he performs a deed—a rather ineffective procedure.

Many human responses have been conditioned in the labora-

tory. One of the most useful and most widely employed is the conditioning of the eyelid or winking reflex (Fig. 34). The original stimulus is a puff of air on the cornea of the eye, resulting in a wink. This response may be conditioned to various substitute stimuli, such as lights, sounds, or tactile stimulation of other parts of the body. Of course, the simple fact

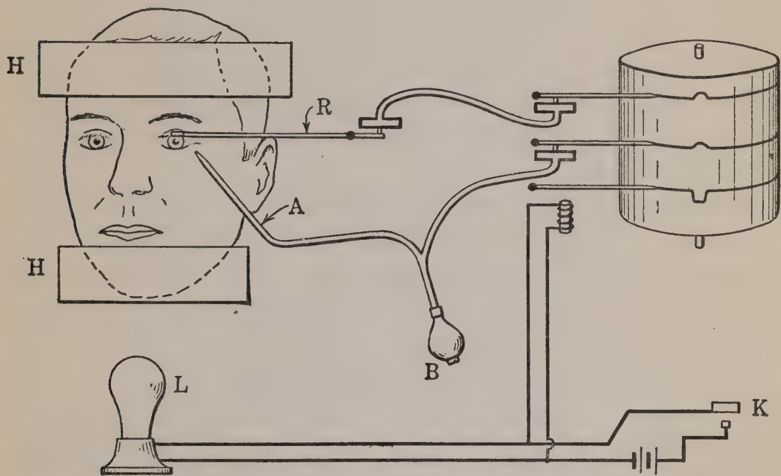


FIG. 34. Apparatus for Conditioning the Human Eyelid Response.

The subject sits with his head firmly supported by the headrest (*H*). The experimenter presses the bulb (*B*) which causes a puff of air (*A*) to strike the subject's eye. The subject's winking response moves the light bamboo lever (*R*) which is attached to his upper eyelid by adhesive tape. This moves a tambour and causes a record to be made on the moving drum kymograph at the right. The air puff is recorded similarly. By pressing the key (*K*) the lamp (*L*) is made to light, and is recorded on the kymograph by a magnetic marker. After the light (conditioned stimulus) and the air puff (original stimulus) have been applied together repeatedly, the light alone will evoke the winking response.

of conditioning is well established and needs little further research, but many other complex and subtle problems are being investigated that help to define the exact circumstances under which associative learning occurs.

Conditioned reactions occur in every normal learning process in ordinary life, as well as in the laboratory. For example, if a child hears someone cry "hot" just as he touches a stove,

and then is slightly burned, the chances are great that in the future he will draw back from almost any object upon hearing that word spoken. This association may be formed on the first occasion at which the child is burned, or it may be built up only after several repetitions of the conditions. Again, the learning of a language is a process of conditioning, in which a word becomes a substitute stimulus sufficient to cause a response originally evoked only by the real object. On certain occasions many of us will jump almost as quickly on hearing a shout of "Snake!" as on seeing the snake, yet a foreigner who has never associated this word with its meaning will not respond in this way.

Conditioning to Intra-bodily Stimuli. From the foregoing description of conditioning it might be assumed that the conditioned stimuli are always external or "exteroceptive." This is not the case. In fact, some of the most important conditioned stimuli are activities of the individual's body itself. This may be illustrated by an experiment (Shipley, 1933). Eleven human subjects were first stimulated by a faint flash of light, followed promptly by a light tap on the lower eyelid. This readily set up a simple conditioned response of winking when the light was flashed. Afterward, the same subjects were stimulated by an electrical shock on the fingers of one hand and a tap on the eyelid, which caused a sharp withdrawal of the hand from the shock and a reflex wink. Two stimuli were now established to evoke the wink response, the shock and the light. In some of the subjects, it was observed, the light now elicited not only the wink, *but also the finger retraction,* even though the light had never been associated with the shock or the finger movement. This rather astonishing reaction is explained as follows (Fig. 35). The shock evokes two responses, a wink and a retraction. The movement of the eyelid muscles in the wink gives rise to sensory nerve impulses from these muscles, or proprioceptive stimuli (P_w). Similarly, the movement of the fingers sets up sensory nerve impulses, or proprioceptive cues (P_{ret}). Since each of these muscle-sense stimuli occurs simultaneously with

the other reaction, conditioning occurs, and P_w becomes connected to finger retraction, and P_{ret} with the wink. There is thus a mutual reinforcement of the wink response and the retraction response, so that each tends to be evoked by the occurrence of the other. This experiment shows how intra-bodily stimuli can become conditioned to various responses.

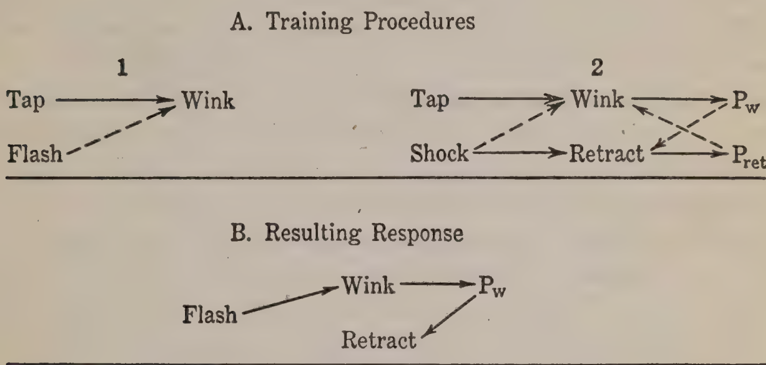


FIG. 35. Conditioning to Intra-bodily Stimuli.

In Shipley's experiment, the subjects were conditioned to wink when a flash of light was given (*A, 1*), and later were conditioned so that a shock caused both winking and finger retraction (*A, 2*). The latter procedure set up an association between the muscle-sense stimuli resulting from winking (P_w), and finger retraction. Subsequently (*B*), the flash of light produced not only winking but also retraction. (Modified from C. L. Hull, *Psychol. Rev.*, 1934, 41:37, 38.)

The conditioning of intra-bodily stimuli has many important applications. Complex serial acts, in which one movement is made after another, depend upon it. When one writes, the making of one letter is the stimulus to make the next one. The baseball pitcher has to "wind up" in the same way each time, for every movement of his contortions has become associated with the effective performance of the final act of throwing the ball. Intra-bodily stimuli are also important in voluntary action and in thinking, as will be described in later chapters.

Indirect and Secondary Conditioning. Associative learning can take place somewhat indirectly by a process known as secondary conditioning. If a simple conditioned response has

first been established, a secondary conditioned stimulus may be made to elicit the same response by associating it with the primary conditioned stimulus. For example, in a human subject a reflex withdrawal of the hand was conditioned to a bell by associating the bell with an electric shock. Then a light was flashed simultaneously with the sound of the bell for a number of times, after which the light was flashed alone. This light, a secondary stimulus, now elicited the response of hand withdrawal. In this case the light was associated with only the "substitute" stimulus, but the indirect association was enough to bring forth the response. The light became substituted for the bell stimulus, as the latter had already become substituted for the shock. A simple example will serve to show the importance of this indirect conditioning in everyday life. A very unpleasant medicine may be taken in a solution of orange juice. Weeks later, the mere sight of an orange may make the person shudder. The sight of the orange was not associated with the unpleasant medicine, and has no direct connection with its present response. The association has been made indirectly, since the sight of an orange has often accompanied the taste of an orange. The *sight* of the orange has therefore become a conditioned stimulus of the second order. The complexity of human learning is such that conditionings of the second order, and possibly even of higher orders, are common. It would be difficult indeed to trace the many successive conditionings involved in learning to write a paragraph or to drive an automobile.

The values that people attach to objects of no intrinsic value, such as money, are obtained by indirect conditioning. In an experiment with chimpanzees some characteristics of indirect values were strikingly brought out (Wolfe, 1936). The secondary rewards consisted of tokens (poker chips) of certain colors and sizes to which were assigned primary reward values, including different kinds of food, water, and activity privileges. The animals were placed in cages which contained food and water-vending machines, and a work machine. The

subjects readily learned to manipulate the tokens in obtaining food from a vendor, and to discriminate between the tokens with and without food value. They then learned to operate the work apparatus in order to secure tokens with which to "buy" food, water, etc. They would not work for tokens that would not "buy" them anything. If the animals had a large number of tokens they would not work very hard to secure additional ones. In social situations the animals exhibited competitive behavior in working for the tokens. One subject even begged for them. This experiment shows that the chimpanzees learned the "value" of each of the different tokens as a result of associating them with particular rewards. In other words, the apes learned by association to attach value to things which in themselves had no real intrinsic value. A human being would not work for a dollar bill if he had not learned through associative past experiences that it will buy things that he wishes. Learning by indirect association is, therefore, one of the more important characteristics of higher animal and human behavior.

Generalization and Differentiation. A newly established conditioned reaction is rather generalized, both as to the stimuli that will elicit it, and as to the response itself. If a dog is conditioned to respond to a tone of one pitch he will immediately afterward tend to respond to a tone of *any* pitch. The initial conditioning therefore applies to a greater situation or class of stimuli, rather than to exactly the stimulus used in training. Also, the dog's response is diffused at first. If he is conditioned to lift the right fore paw he not only makes this movement but also moves all his legs restlessly and stirs about with his whole body. In contrast, the long-trained animal will lift only his paw with great economy of movement. In this respect conditioning is like maturation and trial and error learning. All these processes involve general and undifferentiated behavior at first, followed by greater precision after practice.

Animals can be trained to differentiate among stimuli by the proper type of further practice. The shock (original stimulus)

may be given only with a certain tone, other tones being sounded without the shock. The animal then will cease to respond to the other tones, and will react only when the particular tone is used, showing that a differentiation among stimuli has been made. This is a useful technique for determining how fine a discrimination of sound an animal can make, or whether he can distinguish colors or is color-blind. If he can be conditioned to react to one stimulus and not to another, it is certain that he can tell the difference between them.

The generalization and differentiation of conditioned responses occur quite commonly in everyday life. A baby learns to call the family dog a "bow-wow," but this response is not limited to the dog. It may be generalized to the extent that all four-legged animals are called "bow-wows" at first. Later, when the name "bow-wow" is heard only in connection with the dog and not with other animals, the differentiation is achieved and the name is restricted to the proper use. Generalization also accounts for many irrational likes and dislikes. A person may be disliked when he is first met. This aversion may seem "intuitive" and without basis until further analysis reveals that he is disliked because of some vague resemblance to an old enemy. The antipathy has been generalized, and often, of course, unjustly. On further acquaintance with the new person, differentiation may change the objectionable attitude to a favorable one.

Extinction and Reconditioning. Conditioned reactions may be done away with as well as learned, which is fortunate since many associative conditionings are undesirable. One way in which a conditioned response is abolished is by the unreinforced repetition of the substitute stimulus. If a tone is sounded many times without the shock the dog becomes less and less likely to lift his paw upon hearing it. This process is called the *extinction* of the response. Extinction is best interpreted as a further act of learning. The stimulus of "no-shock" is a signal for the dog *not* to lift his paw, and he learns to do so instead of making the previous response. Similarly, a child who is

afraid of animals will often overcome his fear gradually by associating with animals who do not harm him.

In some instances a conditioned response has been so firmly established that extinction will not take place by this rather passive treatment. It is then necessary to take the more positive measure of training the individual to make a response opposite to the undesired one. This is usually known as *reconditioning*. An experiment conducted by M. C. Jones illustrates the nature of this relearning process. A three-year-old child had a conditioned fear of animals. This conditioning was generalized to such a degree that the child feared rabbits, white rats, dogs, and even feathers. Since these fears did not become extinguished in the ordinary course of life, the reconditioning method was tried. A rabbit was brought into the room and placed at a safe distance from the child. In order to provoke a pleasant response at the same time, candy was given to the child. This was repeated a number of times over a period of days. Each time that the child enjoyed his candy the rabbit moved closer and closer, until finally the child was playing with it. He had become reconditioned because a stimulus originally evoking fear (rabbit) had now been associated with a pleasant stimulus (candy) so often that the fear response dropped out. This reconditioning resulted from two things. First, the child gradually became accustomed to the rabbit since he saw it repeatedly without experiencing harm, and second, the pleasant association provided by the candy linked the sight of the rabbit with a pleasant response. After the retraining the child also lost all fear of rats, dogs, and feathers. A generalization of reconditioning was thus secured.

Conditions Favorable to Learning

Adequate understanding of the learning process calls for an analysis of the external conditions which favor a learning situation. It is impossible to observe directly all the neuromuscular changes that occur during learning, such as the growth of neurons, the modification of the connections between neurons,

changes in conductivity of nerve impulses, and other possible structural and functional alterations. The psychologist has a partial knowledge of these processes; but even so, for most practical purposes the best attack on the problem is to consider the facts obtained experimentally regarding certain influences which aid or hinder learning. These influences are commonly referred to as the "laws of learning," but they are really statements of the *conditions* which favor or hinder learning. They include the laws of *contiguity, effect, intensity, organization, facilitation and interference,* and *exercise.*

Like all other scientific laws, laws of learning are generalizations based upon experimental evidence. In common with other scientific principles also, no law operates alone and without the influence of the others. The statement of each law should be prefaced with the words "other things being equal." Many misunderstandings and incorrect conclusions arise from attempts to apply one principle without considering the influence of other conditions that may be operating as well. The laws of learning are of value because they summarize the results of many experiments in a concise manner. They also emphasize the unity of all learning processes, since the fundamental principles hold for all learning, whether "trial and error," "conditioning," "habit," or "memorizing."

Contiguity. In ordinary language, contiguity means "nearness" or "proximity." As used in psychology today, however, the word refers principally to the nearness of two events in time, rather than in space. The *law of contiguity* states that *in order for association to occur, the associated events must fall within a certain time interval.* It is quite evident that contiguity is the fundamental principle underlying associative learning. Conditioning can occur only if the original and substitute stimuli are simultaneous or, at least, not too far apart in time. If the temporal interval is too long, the association is not built up.

Contiguity appears in selective learning as well as in the conditioning experiments. The successful act is directly fol-

lowed by the attainment of the goal, and thus in a sense becomes associated with it, resulting in the more ready performance of this response on the next occasion. If an animal makes the right response in a trial and error problem, but does not proceed promptly to the goal, learning is not produced effectively. In sequential acts, such as running a maze or memorizing a poem, each part becomes connected to the part performed just before, which is therefore contiguous in time. So pervading is the principle of contiguity in all examples of learning that many consider it to be the primary, most ~~important, and uniquely essential~~ law.

Effect. The principle termed the "law of effect" refers to the influence of the end result of an act upon the readiness with which the act will be acquired. The "effect" of a process upon the individual gives the law its name. Briefly, the *law of effect* states that *a response leading to a satisfying result is likely to be learned; a response leading to an annoying result is likely to be extinguished.* To be merely pleasant is not enough; a "satisfying" act must satisfy or fulfill some need or motive of the individual. The responses that lead to adjustment tend to be repeated upon subsequent occasions, and hence learned. Conversely, that which is annoying or frustrating will not be learned, but will be avoided.

The principle of effect is most clearly illustrated by the trial and error experiments, but it is not absent in simple examples of associative learning. One very old experiment concerned a perch and a minnow placed in a tank of water with a glass plate between. After repeatedly striking at the minnow and bumping his nose on the barrier, the perch finally desisted and left the minnow alone even after the partition was removed. Even in experiments on memorizing it has been shown that pleasant and satisfying verbal materials are learned and retained better than annoying or distasteful passages.

Intensity. The *law of intensity* states that *the rate of learning varies with the strength of the response to the stimulating situation.* In trial and error, the individual will learn more

quickly if the rewards or punishments are more intense. A favored food causes quicker maze-learning than one less well liked, and a strong electric shock causes quicker avoidance than a weak one. In conditioning, a more intense stimulus causes more rapid learning, up to a certain point. Thus in some simple kinds of learning the magnitude of the stimulus may be used to gauge the speed of acquiring.

Intensity means more than the strength of a stimulus, however. A hungry rat will learn more quickly than a fed one, even with the same type of reward. He makes a more intense response to the stimulus. In general, an individual who is better "set," more alert, and more highly motivated has an advantage in learning, for he responds more vigorously to whatever stimuli are presented. In complex human learning intensity enters in the guise of interest, which is a symptom of readiness to respond to certain kinds of situations.

Organization. The *law of organization* states that *learning is more rapid when material is organized into meaningful relationships.* A part of the superiority illustrated by the experiment with the ape is due to this cause. When the factors essential to the solution of a problem are integrated into a meaningful whole so that they can elicit one combined response, learning is easier. The ape previously cited showed evidence of comprehending or perceiving the relationship of the tool to the problem that he solved, and hence excelled the cat who had blindly "stumbled upon" a solution. This interpretation is stressed by the Gestalt psychologists.

The principle of organization is even more evident in the learning of verbal materials. Thorndike (1931) performed an experiment in which series of sentences such as these were read to students:

Richard Thompson worked furiously.
William Adams walked rapidly.
Henry Jones studied carefully.

The listeners were much more able to tell "what word comes

after William?" than "What word comes after furiously?" The association of William-Adams was much stronger than that of furiously-William, although each has equal contiguity. This occurs because the former has a clear and meaningful relationship that the latter lacks. Thorndike has used the term *belongingness* to describe the relationship between two or more things that causes them to be integrated into a whole by the learner. That material well understood is more easily learned has practical implications that need not be enlarged upon.

Facilitation and Interference. In some cases the process of learning one task assists the learning of another. A person who has learned mirror-drawing (cf. p. 111) with his right hand improves in the performance of this act with his left hand, even though none of the same muscles are used. A knowledge of Latin often makes it easier to learn Spanish. In these instances the one function is said to *facilitate* the other. This happens because the two accomplishments have common elements that can be transferred from one to the other. The *law of facilitation* may be stated thus: *one act of learning will assist another act if some stimulus in the new situation utilizes a previously learned response.*

Other cases may be found in which the learning of one thing has an adverse effect upon some other learned act. This is termed *interference.* A baseball batter's skill is said to be harmed by tennis-playing. Practice in memorizing words by rote decreases the ability to learn the gist or meaning of passages. In each of these instances a *different* response is acquired to a similar situation which interferes with the previous reactions. The *law of interference* states that *one act of learning will interfere with another act if some stimulus in the new situation requires a different response from that previously associated with the same stimulus.* Interference, therefore, is a sort of conflict between two responses both of which have been attached to the same stimulus.

Another example of interference results from the attempt

to learn too many things at once. A typical animal experiment illustrates this. Three groups of animals were trained to three habits. One group was allowed one day for each habit. A second group was required to work on the three habits three times per day. The third group worked on each of the problems five times per day. The group learning one problem a day learned more rapidly than the groups that practiced three and five times per day. "Learn one thing at a time" is a good principle, if the things being learned call forth any incompatible responses. Thus it is inefficient to try to learn both French and German together, although one may even facilitate the other if the first language is organized and fixed before the study of the second is begun. These illustrations require no new principle, but come under the law of interference already stated.

Exercise. It is an obvious fact that repetition is required for most learning. Repeated solutions of the puzzle box and repeated reinforcements of the conditioned reaction result in improved learning in the various experiments. The old generalization that "practice makes perfect" has many exceptions, however. The extinction of conditioned responses, in which the repetition of a stimulus *weakens* the response rather than strengthens it, has already been described. Care must be taken to define what is being exercised. Practice undoubtedly may aid learning, but what is learned depends upon the operation of the other laws. Reciting the multiplication tables repeatedly may cause an individual to learn them. On the other hand, compelling a student to read poetry that bores him may very effectively teach him to stay away from poetry during the rest of his life. In still another case, a child may write a misspelled word perfunctorily a hundred times and be quite unaffected. Exercise alone is therefore not a reliable principle, and is the weakest of all the laws of learning. The *law of exercise* can only be stated in this way, that *the repeated occurrence of conditions favorable to learning gives them added*

force. Exercise, without regard to the other conditions of learning, may have positive, zero, or even negative influence.

The Course and Limits of Learning

Since learning is a progressive and continuous modification of behavior, certain experimental methods can be profitably directed toward the study of the process as a whole. Much valuable information has been collected concerning the degree of learning that can be attained by given amounts of practice, variations in the rate of learning, and the limits of learning, or the point beyond which further practice ceases to yield measurable improvement.

Learning Curves. Many learned tasks are of such a nature that the accomplishment or degree of skill present at any period of the learning process can be expressed numerically. In the puzzle box, maze, and many other experiments the *time* taken to achieve one successful solution is a criterion of the degree of learning shown. The number of *errors* offers another way to judge the progress of learning. Obviously, both time and errors decrease as learning occurs. Other experimental materials yield measures of the *amount learned* after varying lengths of practice. Thus, in learning a list of words, the number of words remembered after one, two, three, and further readings of the list traces the course of learning. Very similar is the measure of the *degree of skill* attained after various amounts of exercise. For example, when a subject is learning to hit a target with a ball, the number of hits in each successive series of fifty trials may be used as a measure of learning.

A *learning curve* is a graphic representation of the progress of learning. The measure of learning is plotted on the vertical axis, and amount of practice is shown on the horizontal axis. If time or number of errors is the criterion of learning, the graph progresses downward (Fig. 27, p. 104). If the amount learned is graphed, improvement is shown by an upward trend of the line (Figs. 36 and 37). The learning curves for indi-

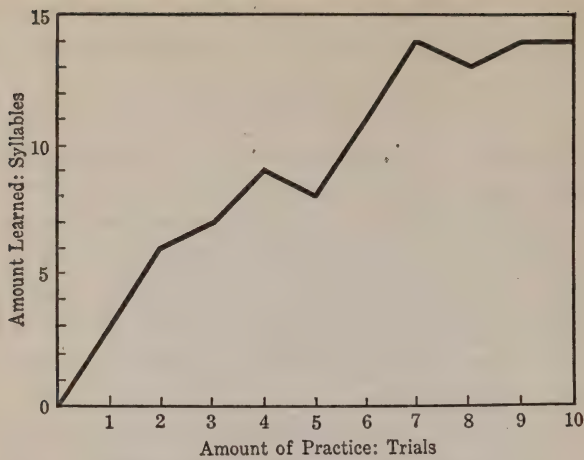


FIG. 36. Individual Learning Curve.

The task was to learn "nonsense syllables" in 14 pairs, so that the proper second syllable could be written when its associated first syllable was seen. This is called the "paired associates" experiment. The graph indicates how many second syllables could be recalled by one individual after each of ten practice trials. Irregularities are due to the impossibility of controlling the conditions of learning precisely.

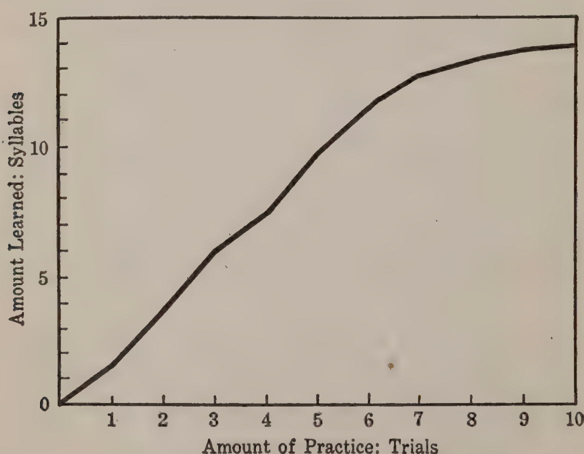


FIG. 37. Group Learning Curve.

This shows the average amount learned by a group of 25 students in the "paired associates" experiment. Irregularities are minimized by averaging the scores made by a number of individuals.

viduals tend to be somewhat irregular because the conditions for learning cannot be controlled with sufficient precision to insure that they will be equally favorable at all trials. Group curves, which plot the average gains of a number of subjects, show fewer irregularities since the average of conditions is more likely to be the same from trial to trial.

The Rate of Progress. Learning curves show a considerable variety of shapes, so that no one form can be considered as

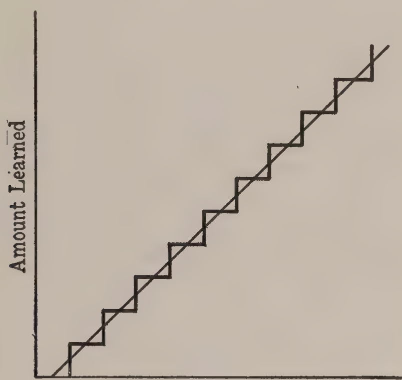


FIG. 38. Theoretical Learning Curve—Straight Line.

If the elements of the task are all of equal difficulty, an equal amount will be learned in each practice period, as shown by the steps. This results in a straight-line curve of learning.

the typical curve of learning. Certain variations in shape can be accounted for by an analysis of the difficulties of the elements that enter into learning. Tasks for which learning curves are drawn are usually complex performances that include many elements, some of which may be harder than others. The simplest case is that in which the elements are of equal difficulty. Since the same number of items are learned in each trial, this gives a *straight-line* representation of learning (Fig. 38).

If the elements of a task are not of equal difficulty there is a general tendency to learn the easiest ones first. As practice goes on, the learner encounters harder and harder ele-

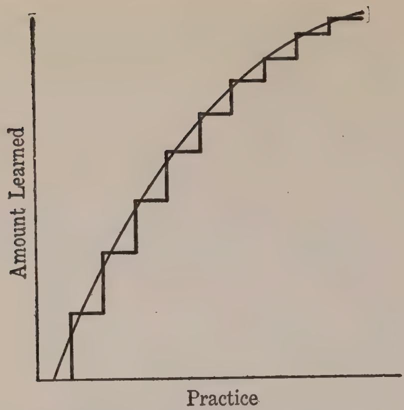


FIG. 39. Theoretical Learning Curve—Negative Acceleration.

As indicated by the steps, a smaller increment of learning takes place in each successive period of practice. This form of learning is usually found when the elements of the task are of unequal difficulty, and when the easier elements are learned first. The resulting learning curve shows negative acceleration, or diminishing returns from practice.

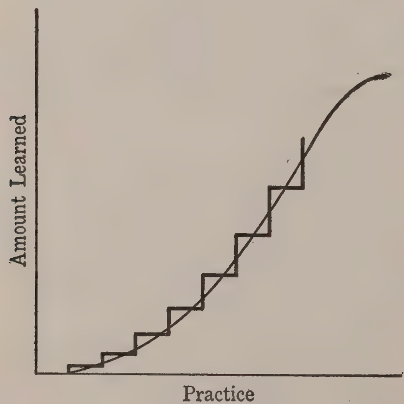


FIG. 40. Theoretical Learning Curve—Positive Acceleration.

The first part of this figure shows an increasing amount learned in each successive practice period, resulting in a positively accelerated learning curve. Positive acceleration occurs when the most difficult elements of the task must be learned first, and when the mastery of these difficult elements makes it easier to learn the subsequent elements. As is shown in the later part of the curve, positive acceleration cannot continue indefinitely, but changes to negative acceleration in the last stages of learning.

ments, resulting in a slowing up of accomplishment because fewer parts can be learned in successive trials (Fig. 39). This gives a learning curve of *negative acceleration* or "diminishing returns from practice." In some cases, however, the opposite effect occurs. Some tasks require the mastery of hard elements at the outset. After these have been mastered, after the subject

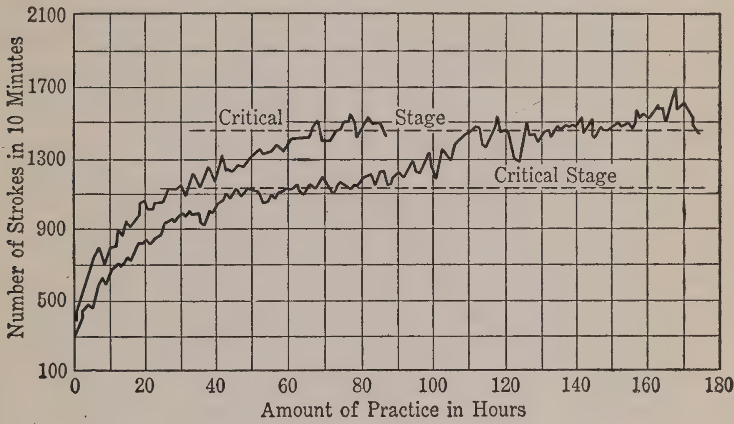


Fig. 41. Learning Curves with Plateaus.

The learning curves show the progress of two individuals in learning to typewrite by the sight method. The first subject (lower line) makes rapid improvement at first, but reaches a first plateau after 40 hours of practice and does not improve again in rate until after the 80th hour. A second plateau occurs from the 110th to the 155th hour of practice. A second subject (upper line) stays on the first plateau for a very short time, but remains on the second plateau from the 60th hour onward. The plateaus are most probably due to the acquisition of inefficient habits that must be overcome before further increase in speed is possible. The small irregularities are due to day-to-day variations in efficiency. (From W. F. Book, *Learning to Typewrite,* Gregg Publishing Co.)

"gets the hang of it," subsequent progress is more rapid. This is termed *positive acceleration*, and is shown in the lower part of the learning curve in Fig. 40. Of course, positive acceleration cannot continue indefinitely, but gives way to diminishing returns toward the end of the learning process.

In prolonged learning processes, such as learning to read, to typewrite, or to telegraph, periods occur during which an individual seems to make no improvement. Such a *plateau* (Fig. 41) is often of practical significance in analyzing the

nature of the learned performance. Plateaus are due to no one cause, but may be occasioned by a number of factors. Some of the simpler causes are lack of motivation, misdirected effort, and fatigue. In other cases plateaus are the result of interference between parts of the task being learned, the appearance of unusually difficult components of the skill, or the acquisition of an inefficient method that must be corrected before further progress can take place. Plateaus are of practical significance because they discourage the learner, and may prolong themselves as a result of the poor motivation engendered. Expect a rise from plateau

Limits of Learning. After many periods of practice the learning of any task becomes subject to such pronounced negative acceleration that no further measurable improvement occurs. The degree of skill resulting from such lengthy practice is spoken of as a *limit* of learning. There are several kinds of limits. The ultimate perfection of performance, which is rarely attained in any real situation, is called the *physiological limit.* This has been reached when the individual does the task so well that his muscles and nerves can do it no faster and no more skillfully. To attain the physiological limit the individual must not only practice long, but also have every other condition of learning at the optimum, including motivation, effect, intensity, organization, and facilitation. Since all these conditions are seldom at their best, a perfect performance is a rare occurrence.

In most instances the top level of a curve of learning may be styled the *practical limit.* The practical limit is the highest level attainable after prolonged practice under the average conditions of learning that are present in ordinary situations. It is valuable to know what the practical limit is for various tasks. It may be known, for example, that twice as much practice in reading beyond a certain amount will give only ten per cent greater efficiency. If this is the case, the time may be spent more wisely on other studies rather than in wasteful effort. Of course there are some situations in which the last

measure of efficiency must be squeezed out at no matter what cost. The runner who is one per cent more efficient than his opponent will win the race.

A plateau may be mistaken for a limit of learning if it is very prolonged. In a number of industrial experiments the output of skilled workers has been measured and found to be constant over a period of years. It thus appears to be a practical limit. But improved incentives in the form of bonuses, higher wages, personal competition, or better working conditions have been found to increase these "limited" performances greatly. Most "practical limits" are probably long plateaus that never have been broken up because the proper conditions for further improvement have not been offered.

The statements that have been made concerning the limits of learning pertain to the ultimate efficiency with which a person can perform a single task. This is limited. But there is *no limit* to the number of different things that an individual can learn. The brain is *not* a bucket of limited capacity that can "hold" only so much. As long as conditions are favorable for learning, and as long as the organism is intact, new things can be learned every day.

Habits

The Concept of Habit. A habit is *any well-learned form of behavior.* The concept of habit is used somewhat more inclusively in psychology than in popular speech. An everyday appraisal of a man's "habits" usually refers either to his typical routine of life, or else to his punctuality, trustworthiness, sobriety, and the like. All these are habits, to be sure, but many other forms of habits are also recognized.

Habit is defined most clearly by noting some of its most essential characteristics, which may be derived from the facts about learning. Since a habit is well learned, it is performed rather *automatically* when the required stimulus occurs. It requires a minimum of choice, of discrimination, or of trial and error. By habit the person signs his name fluently, reads

without having to ponder on each word, or buys his accustomed newspaper without a glance at its competitors. Another characteristic of habit is that it *interferes* with any incompatible form of behavior. Well-formed habits are hard to change, and sometimes crop out inappropriately. By habit the ex-soldier salutes the officer whom he passes on the street. Closely allied is the fact that a deeply learned habit is *motivating.* When the stimulus for it is presented, the person has an impulse to act in his habitual manner. Thus one speaks of "the force of habit," a figure of speech that is not inappropriate psychologically.

Another way to define habit is by excluding that which is *not* habit. At one extreme, reflexes and other simple muscular acts that are formed primarily by maturation are not habits. On the other side of habit are the more complex and variable forms of behavior ascribed to voluntary action, reasoning, or problem-solving. Since habit comprises all dependable forms of behavior between reflex and reason, it is clear that it includes most of human activity. A workman operates a tool skillfully because of habit. The ability to read is a habit, as are also skills in arithmetic, spelling, and other well-learned school studies. Driving an automobile, playing tennis, engaging in one's occupational activities, are all examples of habits. More broadly, habits include one's characteristic emotional reactions, the responses that are typically made to frustration, one's attitudes, prejudices, and fixed beliefs. An individual's personality consists largely of his habits of reacting to social situations, as will be described in a later chapter. Since habit is such an inclusive concept, its importance in life cannot be questioned.

How Habits Are Organized. A habit is a complex act and cannot be represented fully by a simple $S \longrightarrow R$ formula. Two modifications of this diagram are necessary to include the principal characteristics of habit. First, a habit is a *sequence of responses,* consisting of a series of reactions that begin when some general situation occurs, and end when some result

is achieved. An example of how a "chain" of stimulus-response units functions in behavior may be found in walking. The sight of a friend across the street may serve as an initial stimulus, and the release of motor impulses to the muscles of the left leg represents the first response to this stimulus. As the left leg moves forward, proprioceptive sensory impulses return from these muscles to the central nervous system, where motor impulses are now sent to the muscles moving the right leg. As these stimulus-response mechanisms continue to function repeatedly, the major response of walking results. The behavior has taken place through the operation of a chain of stimulus-response connections.

Second, habits are *relatively variable*. Each complex habit represents not just one chain of stimulus-response units, but

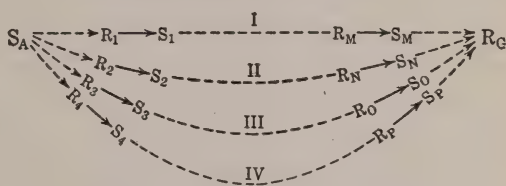


FIG. 42. The Habit-family Hierarchy.

The figure represents four stimulus-response chains any one of which may lead from the original situation (S_A) to the goal response (R_G). The preferred habit is I, the second in the hierarchy is II, etc. (From C. L. Hull, *Psychol. Rev.*, vol. 41, 1934.)

several. This combination of habit sequences is illustrated in Fig. 42. Several stimulus-response chains operate in bringing about the end result, or goal response, (R_G), from the original situation (S_A). Each chain represents different movements, but is related to the others because it leads from S_A to R_G. For example, a man may have a habit of driving from his home to his office by a certain route. But if this road is blocked he can take some other familiar route and arrive at the same destination. A thoroughly learned family of habits for getting from one place to another offers quite a number of alternative itineraries. One further fact about this "family"

of habits is notable. One route is the *preferred* pathway, another is second in preference, and so on. The habit chains therefore comprise a "hierarchy" of responses, that is, a number of alternatives having a ranked preference. The total habit may be termed a *habit-family hierarchy* (Hull, 1934).

There are many illustrations of habit-family hierarchies other than the spatial example that has been given. A mechanic usually has a preferred method of doing some job, such as assembling an electric motor. But if his preferred reaction is blocked in some particular instance, he can do the task in one or more other ways. In fact, it is the possession of more than one habit chain for a given situation that makes him skillful. The person with only one way to try has less knowledge; his habit is less fully organized and hence less useful. Competent behavior consists of a fully developed hierarchy of habits for each typical situation, and distinguishes the capably trained man. Another illustration of this from a more intellectual sphere may be given. A real scientist has more than a command of the separate techniques of his field; he has organized them into "families" of knowledge that are thoroughly integrated and meaningful. He knows alternative methods for solving problems, and can quickly shift from one to another when necessary. A partly trained student of science, in contrast, knows only one method for doing each task, or else has not integrated the various possible methods into a smoothly operating habit.

An important fact about the habit-family hierarchy is that a new use for one chain of the family immediately transfers to all the other chains. As a simple example, if one finds that a friend lives on a certain street, all the previously learned ways for reaching that street are promptly integrated to the new demand. The individual does not merely learn the route to his friend's house that he took upon discovering it, but all the known alternative routes also become effective. On the next occasion he can, promptly and without further trial and error, take a way that has never before led to that particular goal.

Similarly, a new use for a scientific technique can be applied immediately to all the variations of that method that are members of the same habit family. This conception helps to explain instances in which a learned task is grasped immediately without random trials.

Habits in Everyday Life. From a practical point of view, habits are both assets and liabilities. Walking would certainly be a laborious process if it were necessary to think how to place one foot in front of the other. Consider the discomfort that would result if we had to plan to open the mouth and chew while eating. Habits quite obviously save much effort in our daily routine and make possible the continuous acquisition of new and more complex accomplishments.

On the other hand, habits can be and often are liabilities. They tend to confine us to the old and the traditional. Wholesome conservatism as a matter of habit may serve us well on one occasion, but may be a serious disadvantage on another. An executive may well prevent his own advancement by wasting his time on routine tasks that might be delegated to a clerk. "Progress" often is retarded for many of us because of our inability to rid ourselves of old habits. One reason why many people find it difficult to accept new ideas is because they run counter to their old habits of thinking. There can never be any specific rule as to how far a person should become "set in his ways"; but if living by old habits is carried too far, interference prevents desirable elements of new learning.

Some habits, such as skills, are directly and deliberately acquired. Others are learned as a result of indirect influences. The circumstances under which one has learned to operate a machine or play tennis are often known and can be controlled. But the habits that are developed by slight, unanalyzed, everyday influences play an even greater rôle in human behavior. Attitudes, prejudices, traits of character, and other personal habits come under this category, and these habits most often determine a man's success or failure in life.

Chapter VI

EMOTIONAL BEHAVIOR

The Nature of Emotion

Every person acquires a large number of useful habits that enable him to adjust successfully to the situations presented by a normal environment. From time to time, however, individuals encounter situations to which they cannot adjust ~~readily~~. When this occurs they may become disturbed and disorganized, displaying *emotional behavior*. Everyone can recall situations that have provoked emotion. Startle or fear may be produced by a sudden and unexpected slip or fall. A persistent interference that cannot be overcome or avoided may arouse a person to anger. Exceptionally good news often produces excitement. In each of these cases, the individual is stirred up, disorganized, and confused because he cannot make a suitable adjustment to the situation.

Emotion, then, is a generally disturbed condition of behavior resulting from the lack of an habitual adjustment. This condition is manifested in three ways. First, emotion is evidenced by *overt behavior*. The emotionally responding organism is excited and restless, and acts vehemently. The angry person, for example, clenches his fists, grits his teeth, frowns, and shows other signs of excessive muscular tension. Second, emotional behavior involves profound *internal changes* in the vital systems of the body. When emotion is aroused, the heart thumps, breathing is heavy, the pulse beats rapidly, and blood pressure increases. All these physiological changes indicate a disturbance of bodily or organic processes. Third, emotion includes a peculiar sort of *conscious experience*. The

individual reports an awareness that is unlike other forms of experience. Also, he is mentally confused, incoherent, and incapable of calm deliberation.

In common speech, emotional behavior is often regarded as made up of a large number of separate so-called "emotions," designated by such terms as fear, rage, jealousy, excitement, love, or sorrow. Superficially, these conditions seem quite different, but they really have much in common. In each, the individual's overt behavior is poorly adapted to the situation at hand, and his habits are inadequate to fulfill his needs. Physiological studies also show that the internal changes are very similar in all the so-called emotions. The various experiences of emotion cannot be distinguished or separated by examining the bodily changes that are produced. Most significantly, developmental studies show that emotional behavior is derived from a common beginning in infancy, from which the more specific forms are evolved. For these reasons, psychologists speak of *emotion* in the singular, rather than of a plurality of "emotions."

The Development of Emotional Behavior

The overt behavior of emotion, like all other forms of response, develops gradually from infancy to adulthood. The newborn infant shows no specific or definite emotional responses, just as he lacks specificity in other reactions. Through a gradual process of maturing and learning, distinct forms of emotional expression appear. The development of emotion, therefore, once again illustrates the broad principle of growth from *general to specific* behavior.

Undifferentiated Emotion in Infants. The first emotional responses of the newborn are diffuse and undifferentiated. Infants respond emotionally to a number of stimuli, but their reactions to various situations are not specific. Several studies have shown that it is impossible to tell from an infant's responses what "emotion" he is undergoing or what stimulus evoked it.

One of the most striking evidences that infants' emotions are not specific comes from the experiment of Sherman that was cited in Chapter I.[1] Adult judges were quite unable to discriminate between the emotional responses of infants to various stimuli. Responses caused by hunger, pain, restraint, or loss of support were identified no better than by chance. But when the same observers were permitted to see the stimuli that provoked these responses they judged them according to the conventional conception of the usual results of these situations. This demonstrates that common judgments of infants' emotions are based on the adults' interpretation of the situation, and not on any specific behavior manifested by the infant.

In another method for studying emotion in infancy, consecutive observations of the development of emotional behavior are made. In a research of this type Bridges made daily observations on more than sixty infants. She concluded that during the first two months of life the infant shows only one type of emotional expression, which is best designated as "excitement." Other more specific emotional reactions emerged gradually from this initial response during the first year.

The Development of Emotional Patterns. During the first two years, several rather specific emotional responses become differentiated out of the vague and general emotion of excitement. Bridges (1932) has described three aspects of early emotional development. First, an increasing number of distinguishable forms of emotional behavior become evident. Second, as the child acquires more specific habit responses, each of these emotional patterns becomes more definite and more clearly differentiated from the others. Third, a given emotional pattern, such as anger, is typically aroused by different situations at different ages, although the situations are usually of the same general type.

Some excerpts from Bridges' detailed observations of emo-

[1] See p. 12.

tional devolopment from birth to eighteen months of age illustrate these three principles of emotional growth.

The one-month-old baby showed excitement in accelerated movement and breathing, upon any excessive stimulation. He exhibited distress by crying, reddening of the face and tense jerky movements at painful and other disagreeable stimulation. But he was more or less passive and quiescent when agreeably stimulated.

By three months of age the child was seen to exhibit delight in smiles, deep inspirations and somewhat rhythmic movements when his bodily needs were being satisfied. Between three and four months angry screaming and vigorous leg-thrusts, in response to delay in anticipated feeding, were observed. A few weeks later anger was aroused when an adult's playful attention was withdrawn.

Distress and delight came to be expressed more in specific vocalizations with increasing age. General body movements gave place to precise responses to details of a situation. A four-month-old baby would laugh aloud with delight and cry tearfully when distressed. A child of five months was seen to cough and reject foods of a certain taste and consistency in incipient disgust. He would reach toward objects that caused delight. By six months of age he showed definite fear when a stranger approached. He remained motionless and rigid, his eyes wide and staring. It is possible that "noninstitutional" children might show fear in response to other unusual or unexpected events a little earlier than this. There was little variation in the daily routine of the children under observation, and fear was a rare occurrence.

By seven months of age the child showed positive elation, and renewed his activity as a result of success in his own endeavors. At eight months he began to show reciprocal affection for adults, and by twelve months, spontaneous affection. Delight was manifested in much laughter, bouncing up and down, and banging with the hand.

Between nine and twelve months of age the hospital babies would hide their heads, like ostriches, upon the approach of a relatively unfamiliar person. They would scream and become flushed with anger when their efforts or desires were thwarted; and they would cry out in fear and sit motionless after perceiving themselves falling.

It was observed that a child learns to kiss soon after twelve months of age, and by fifteen months he expresses his affection for other children. Anger over disappointment becomes more dramatic in its manifestation. The true temper tantrum makes its appearance roughly about fourteen months of age. By eighteen months anger at adults is expressed in obstinate behavior; and annoyance at interfering children is manifested in hitting, pulling, and squealing.

Eighteen-month-olds would constantly seek the attention of adults, and take great delight in running about and making noises. One or two children of this age showed depressed, and others angry, jealousy when another child received the coveted attention. A few specific fears were noticed; and several children developed particular affectionate attachments.[2]

Bridges' findings are presented more systematically in Fig. 43, which shows the evolution of the various emotional forms, and the approximate ages of their appearances.

It is evident that the differentiation of emotional responses is in large measure a learning process. At an early stage, all sorts of annoying stimuli result only in the generalized emotion of distress. As the infant grows older he perceives situations more clearly and learns by experience how to deal with them. Situations such as restraint become associated with the struggling movements that sometimes result in successful adjustment. From this source the emotional pattern of *anger* or *rage* is differentiated. Situations that are sudden and overwhelming, such as loud noises or falling, come to evoke a different reaction, and the *fear* response arises. Later, there develop the even more elaborate reactions of jealousy, joy, grief, disappointment, and the like, which demand broader comprehension and wider experience with social situations. Since they are the learned derivatives of the simple common emotion of infancy, these various "emotions" are best designated as *emotional habits.*

Stimuli for Emotion. In describing the development of emotion little has been said about the stimuli that typically arouse it. In past years, a large number of situations were believed to be native or unlearned stimuli for various emotional patterns, chiefly because they usually aroused emotional responses in adults. Among the situations supposed to be effective producers of fear, for example, were named "the dark, furry animals, strangers, high places, vermin, and dead bodies." Recent developmental studies give little support to

[2] K. M. B. Bridges, "Emotional Development in Infants," *Child Development*, 1932, 3:339-340.

Note!

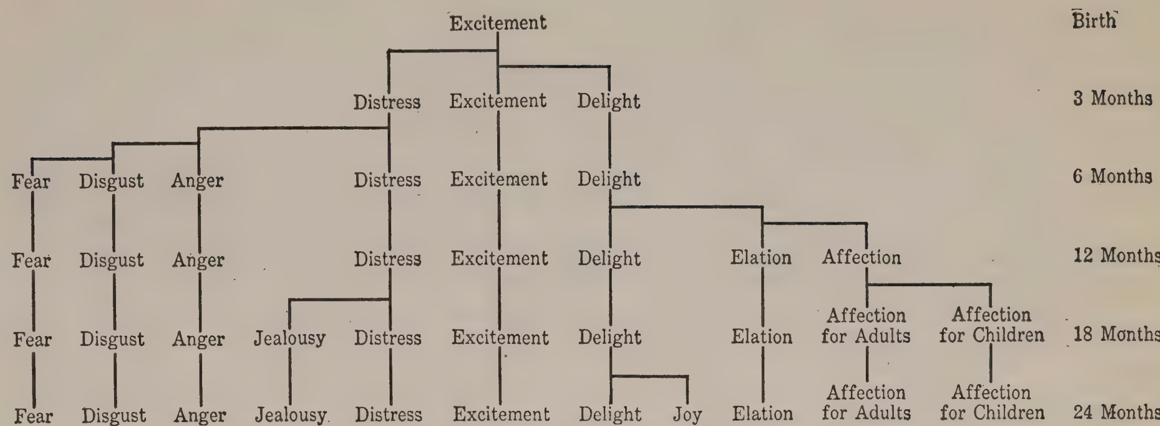


FIG. 43. The Development of Emotion.

The chart shows the ages at which various emotional responses appear during the first two years of a child's life. The more complex emotional patterns are derived from simpler forms by processes of differentiation. (From K. M. B. Bridges, *Child Development*, 3:340, 1932.)

such an account. Careful observations of infants and small children show that dogs, cats, rats, birds, insects, slimy substances, fire, and darkness do not produce uniform or native reactions of fear, disgust, or any other emotion. It is believed, therefore, that emotional responses to these stimuli must be learned.

Laboratory experiments show that emotion is generally aroused in infants and children by pain, rough handling, loss of support, unexpected loud noises or appearances, restraint, and the hampering of activity. These situations have much in common. At the most primitive level they represent bodily injury or excessively intense stimulation. At later ages, dangers, anticipated injuries, or overwhelming situations become effective substitutes. In general, emotion is produced by situations to which the individual is not adjusted. In early life these situations are relatively simple, few, and directly concerned with the organic welfare of the individual. Later, the stimuli for emotion become greatly extended through the growth of comprehension and the establishment of habits.

Emotional Conditioning. The large number of situations that will excite emotion in older children or adults is in marked contrast to the very few that evoke emotion in infancy. In addition to manifesting emotion in situations that really obstruct the course of adjustment, adults often respond emotionally to harmless or irrelevant stimuli. Thus many people are afraid of dogs, of mice, of thunderstorms. They become enraged when spoken of slightingly, or become excited on encountering certain persons. Since these situations are certainly not original stimuli for emotion, they must have become so by acts of learning. In fact, almost any stimulus can be connected to an emotional response by the process of *conditioning* which was described in the preceding chapter.

The conditioning of emotion has been demonstrated by many laboratory experiments. In one early experiment by Watson (1921) the subject was an eleven-month-old infant who had previously shown only favorable reactions to dogs,

cats, rabbits, and white rats. This infant could be stimulated emotionally by loud noises, such as that made by striking an iron bar with a hammer. The conditioning was performed by placing a white rat near the child and producing the loud noise just as he touched the animal. This resulted in an immediate emotional response. After seven combined stimulations of this sort, the infant cried and started to crawl away immediately when the rat alone was presented. Thus he was *taught* to fear a harmless and previously acceptable object. Emotional responses are notable for the generalization of conditioning that usually occurs. The child conditioned to fear a rat also showed fear of a dog, a cat, and even a piece of wool, to all of which he previously had made only positive responses. — generalization

In ordinary situations of life, the processes of conditioning are psychologically the same as in the laboratory, but they are seldom as efficiently observed or as carefully analyzed. One case in which accurate observations of an infant were made may be cited.

> At the age of five months, the infant was taken to a physician's office for his first inoculation against diphtheria. He had been in this office several times before without any notable display of emotion. The infant remained calm until after the insertion of the hypodermic needle. When it was inserted he shuddered, and then, after about three seconds, cried convulsively and could not be quieted for several minutes. On the second visit, ten days later, the infant was quiet until he saw the physician approach with the hypodermic syringe. Then, before being touched, he wailed loudly. After another ten days, a third visit produced crying immediately upon being carried into the office. The fourth call resulted in loud crying as soon as he was brought into the outer waiting room. The conditioning therefore spread gradually outward to situations more and more remotely associated with the painful stimulus. Furthermore, he now cried when placed prone upon a bath table at home, which somewhat resembled the physician's examining table. This persisted for several months. At sixteen months of age, nearly a year later, he still cried upon entering the physician's office, although no further injections or other painful treatments had been given there in the interval.

Many emotional reactions are conditioned by less obvious

2-3 not present!

1. fear
2. grief
3. startle
4. anger

means. Social and verbal conditioning accounts for a large number of absurd fears. A child's playmates may frighten him with stories of goblins, or with real snakes or animals. Parents and servants sometimes control children with threats of the policeman or the "big bear," or of being locked in a cupboard, resulting in emotional attitudes that persist for a long time. Fears of mice, of snakes, or of thunderstorms are often conditioned because a parent is afraid of these things. Seeing the parent's fear, the child becomes afraid too, and often acquires a lifelong habit in this manner.

Reconditioning of Emotional Reactions. Since emotional reactions are so readily conditioned to new stimuli, it is surprising that people are not hampered throughout life by a large number of such responses. It is indeed fortunate that there are means for curing or "reconditioning" undesirable emotional patterns. The remedy for an unfortunate emotional response, like its cause, is a process of learning. The essential requirement is the association of the emotion-provoking stimulus with a different response that is not emotional in nature.

The process of reconditioning, which has been described in the preceding chapter,[3] is especially valuable in ridding an individual of a conditioned emotional reaction. This is carried out by associating the emotion-arousing situation with a strong pleasant response. An example is the experiment of M. C. Jones, already cited, in which a child who feared animals was reconditioned by the gradual introduction of a rabbit while the child was pleasantly occupied. The retraining takes a long time, more than forty experimental sessions having been required in Jones' experiment. Laboratory evidence also shows that social stimulation is useful in reconditioning emotional reactions. If a child sees that other children do not fear a situation, his fear may be overcome more easily.

On the negative side, it has been shown that mere disuse does not appreciably affect a conditioned emotional reaction. For an individual to avoid the emotional stimulus, therefore,

[3] See p. 121.

overcoming unnecessary behavior { 1. Reconditioning
2. Develope adequate adjustment to situation

merely postpones overt outbreaks; it does not really cure the undesired reaction. Fears have been known to persist through years of disuse, only to occur again when the conditioned stimulus is once more encountered. Neither does repeatedly facing the fearful situation do much good, unless a new and favorable reaction to it is elicited, as described in the preceding paragraph. Compelling an individual to face a situation that he fears may, in fact, reinforce the emotional reaction. Verbal methods of retraining are also of very limited value. It is useless to attempt to persuade a person that his fear is groundless; to ridicule the fear may actually make it worse.

Emotional Response Patterns in Children and Adults

Through processes of maturation and learning, older children and adults develop patterns of differentiated emotional behavior that are designated by such terms as fear, grief, disgust, anger, jealousy, excitement, joy, and love. Although these emotional habits are greatly modified by intellectual factors, they are sufficiently common and uniform to warrant a brief description. Emotional habits are determined in large measure by the cultural environment in which the individual lives. There are some essential similarities between the "emotions" of, say, Scandinavians, Chinese and Hottentots, but there are also many significant differences.

Fear. Fear is the most extreme and, at the same time, the most typical of emotional reactions. It most clearly satisfies the criterion that emotion is a response to situations calling for adjustments that the organism is unprepared to make. Fear is a pure state of nonadjustment, and has no utility that can be discovered.

The most common stimuli for fear in older children and adults are intense, sudden, and unexpected noises, movements, or appearances. Real catastrophes, such as explosions or automobile wrecks, call forth fear that may almost be considered justified. Prospective injury becomes capable of arousing the response when the individual has had enough experience to

foresee the outcome. In addition, there is the host of conditioned fears evoked by substitute stimuli that are not really fearful. The characteristic motor response in fear is a sudden extension of the arms and legs and a tenseness of the entire musculature. This response is readily seen in young children, but often becomes so overlaid by other muscular habits in adults that it is very brief and superficial. The typical visceral and glandular changes of emotion are maximally present in strong fear, and the mental disorganization is also marked.

One kind of irrational fear reaction, known as *phobia*, is of special interest. The sufferer from a phobia feels a strong fear of some harmless situation. He admits that the fear is foolish, but is unable to control it. Most significantly, he cannot recall any experience that would account for its acquisition. For example, one young woman feared for many years to stand near an open winow when it was dark outside. Another had a fear of eyes and was unable to look anyone in the face. Other common stimuli for phobias are high places, closed rooms, crowds, and animals. It is now generally believed that phobias are conditioned fear reactions, complicated by the forgetting of the causal experience. This forgetting sometimes operates because the experience occurred very early in life. In other instances, it is a "protective" forgetting of a shameful or otherwise unpleasant experience, a phenomenon to be described in a later chapter. The phobia persists because the subject, having "forgotten" the causal incident, is prevented from making a readjustment to it.

The cure of a phobia, like that of any other emotional reaction, involves making a new response to the fearful stimulus. Sometimes this is effected by assisting the sufferer to recall the experience by which the fear was acquired. Usually this experience, once recalled, seems petty and inconsequential. An adjustment is made to it, after which the phobia usually disappears. Other devices may be used, however. The girl who feared open windows was made to stand before them each night, and then to write a full report of the experience. This

Reconditioning
Intellectual analysis

practice caused her to take an intellectual and analytical attitude toward the stimulus instead of a nonadjustive one. A different response was set up by this procedure which greatly reduced the frequency and intensity of the spells of fear.

A number of other emotional habits, or so-called "emotions," are somewhat allied to fear. Reference has already been made to *distress*, an infantile type of emotional response that is retained in some degree throughout life. *Grief* is probably derived from distress, and is dependent upon an intellectual development sufficient to understand the loss or injury of loved ones. *Sympathy* is related to grief, and is probably socially conditioned. *Disgust* seems also to be social in origin, since the accepted habits of some groups of people are disgusting to others. Disgust at foul odors, loathsome sights, and similar stimuli involve stomach reflexes allied to those of real nausea.

Anger. Anger or rage is a strong emotional reaction usually elicited by an interference with activity on the part of persons or obstacles that cannot be overcome. In childhood, the stimuli for rage are comparatively direct and simple. Restriction of movement, the sudden snatching away of a toy, or interference with a play activity that is in progress will usually call forth anger in a child. Other frequent causes of anger reported by research studies include disagreements with playmates, direct conflict with authority, the enforcement of routine physical habits, and the child's inability to complete a task. As the individual grows older, outbursts of anger diminish in frequency, and the typical stimuli are somewhat different. Symbolic restraints, such as verbal refusals of permission, the necessity of changing one's plans, or slights and insults become the more potent causes of anger.

Among adults, anger is often manifested in a milder form that may be termed "annoyance." Some of the most common annoyances were determined by Cason by means of a questionnaire answered by several hundred persons of all ages. Many of the most frequent causes of annoyance are unpleasant associations relating to filth, germs, and untidiness. These are

typified by such situations as "a person coughing in one's face," "a dirty bed," and "to see a man spit tobacco juice." Another very common annoyance is personal interference, such as "to be interrupted when talking" or "to be pushed in a crowd." A more subtle and frequent annoyance arises from seeing another person in an embarrassing situation, such as "a public speaker talking in a halting manner." Other common annoyances involve undue familiarity on the part of a stranger, and criticism, sarcasm, or derogatory comments from anyone. Quite pronounced age and sex differences were discovered with respect to some annoyances. To see an automobile driven carelessly is much more annoying to older than to younger people. "A person commenting on my weight" proves much more annoying to women than to men. These little annoyances are representative of the causes of everyday anger of mild degree. In general, they confirm the generalization that anger is the typical response to things that interfere with one's activities, self-respect, or standards of decency.

The response of anger or rage is not clearly distinguished from distress during the earlier years of life. It consists of random kicking and striking, of stiffening the body, crying, and often holding the breath. With increasing age, the anger responses are directed more specifically to the obstructing object or person. Fighting is a specific anger response among children, but it is an inefficient and uncontrolled sort of fighting, not likely to succeed against cool and calculated aggressiveness. An emotional response typical of early childhood is *negativism*; this is a form of rage in which the youngster refuses to cooperate in any way, and often does the opposite of what is requested. Negativistic behavior reaches its peak at two and a half to three years of age, and occurs much less often among older children.

In adulthood the overt behavior of anger may be almost entirely controlled. The angry man usually reveals his state only by certain expressions of emotion that are attenuated remnants of the more complete primitive response. The clas-

sical descriptions of the expression of anger note that the face is flushed, the forehead frowns, the eyes are partly closed, the nostrils are distended, the teeth are bared, the fists are clenched, and the whole body is tense. As a matter of fact, there is much variability in the expression of anger, and the classical list of its symptoms is often violated by omission and modification. A description of the expression may be useful to an actor who wishes to simulate rage, but it is not a very precise description of how an enraged person must appear in an actual situation.

People show marked individual differences in their susceptibility to anger, some becoming angry frequently and at slight provocation, while others are very restrained. There is evidence that these variations are due to experience and training. If an individual has a "terrible temper" it is most probably due to his having learned no better way of responding to frustration. In studies of anger among children, Goodenough (1931) traced many of the causes of uncontrolled temper. The person who is frequently "given in to" when he becomes angry is likely to have more fits of rage, since this reaction is then adaptive in an inferior sense because it gets him what he wants. Temper was found to be inculcated by parents who were critical of their children and greatly concerned as to whether they were "good" or "bad," whereas the children of tolerant parents grew up with fewer anger reactions. The alternative to anger is a constructive approach to difficulties which regards them as problems to be solved or as obstacles to be overcome. As each person acquires a greater number of adaptive habits for dealing with his environment the number of his anger responses should diminish.

A variety of terms is employed to designate common emotional habits that are related in some degree to anger. *Jealousy* is a persistent angry reaction against a person who receives affection, advancement, or other good things that the subject feels to be his own. It differs little from anger except in the chronic character of the response, and the specific and personal nature of the stimulus. *Resentment* probably differs from

jealousy only in degree. *Hate* is a compound of anger and fear, also directed against some specific person or group. *Embarrassment* may be classed as a mild, angry confusion resulting from an awareness of inadequacy. None of these responses is very specific, and they are certainly not independent and native "emotions." They are terms descriptive of a total situation-response relationship, for these "emotions" cannot be defined in terms of the responses alone, but only with reference to the situations that arouse them.

Delight, Joy, and Laughter. Superficially, forms of behavior such as joy, elation, and laughter seem very different from the emotions of fear and anger, yet they also bear some striking resemblances. The greatest difference, of course, is that anger and fear have an unpleasant feeling tone, whereas joy and laughter are pleasant. The former are generally avoided, but people will deliberately seek the latter. Delight and similar functions have much in common with emotion, however. The joyful individual is stirred up and excited. He shows some disorganization of ordinary habits. Visceral reactions, consisting of changes in heart beat, blood pressure, and respiration, are also present in joy. It is fair to conclude, therefore, that states of this sort should be called emotional.

Rather early in life, delight is differentiated from the primitive emotional response of excitement. The childish responses of delight include smiling, laughing, exclaiming, and general motor activity such as jumping up and down and clapping the hands together. These responses are modified very little by maturity. They become somewhat diminished in intensity, but upon extreme provocation many adults will show all the evidences of childish glee.

There is an interesting relationship between the stimuli for delight and those for rage or fear. Falling usually elicits fear, but to be tossed into the air by a familiar adult usually causes delight in a youngster. Similarly, if a stranger jumps out unexpectedly with a loud yell, fear may be provoked in a child. But when a familiar adult or a playmate jumps from con-

cealment, not entirely unexpectedly, and loudly yells "boo," a young child will usually respond with peals of laughter. Mauling a child or playing "rough-house" with him may result in rage or delight, according to the circumstances. The same types of reaction are not absent from adult behavior. A roller-coaster is regarded as an amusement device, yet it stimulates one of the most dependable causes for fear, namely, loss of support. At a more mature level, a golfer may rage at the sand traps and curse when he gets into the rough, yet he seems to take delight in the sport as a whole. From these illustrations a tentative generalization may be drawn. When a sudden, intense stimulation or a prospective difficulty results in failure of adjustment, fear or rage is produced. But when the intense stimulus brings no injury, or when the difficulty is easily overcome, delight, joy, and laughter are the typical responses. The reaction is to some degree emotional in either case.

Among older children and adults, laughter often results from hearing a funny story or joke. Volumes have been written on the psychology of humor, but a few conclusions may be given here that are not out of line with the analysis of delight that was just made. A good joke has a sudden turn in its sequence, a "point" at which the meaning is given a twist from the serious to the ridiculous or incongruous. Interest and tension are built up by the preamble, then suddenly released when the point is reached. Many jokes represent their subjects as stupid persons, and the hearer has the added satisfaction of thinking how much cleverer he is. Other humorous situations, from the custard-pie comedy to considerably more sophisticated levels, represent the doing or saying of things that a person would like to do, but from which he is ordinarily inhibited by convention. Humor serves an adjustive purpose by releasing tensions, making sport of serious considerations, and turning one's feeling tone toward the pleasant.

Affection and Love. It is doubtful whether affection and love are emotional states in the psychological sense, but they have the support of long-standing literary usage as "emotions."

Most conditions of affection lack the violent nature of the other emotional habits that have been described thus far, and are calming rather than exciting physiologically.

Affection begins at an early age when the infant smiles at the sight of his mother or other caretaker. This is a conditioned reaction founded upon the satisfaction of the infant's organic needs for food, warmth, and comfort. Since some adult has to be present whenever these needs are fulfilled, the mere presence of the adult comes to be a satisfying stimulus. Fondling, playing, and other causes for delight strengthen the affectionate responses. There is no native affection of children for their parents, but under normal circumstances a strong feeling of attachment is created during the early years. This becomes extended to include other familiar adults, and also child playmates with whom favorable relationships are established.

There is a considerable relationship between the development of affection and that of fear and rage. Unfortunately, the child who is stimulated to an excessive affection for his parents learns by the same events to be dependent upon them, to be unable to solve difficulties by himself, and to expect everything to be made easy for him. The "spoiled" child is not only unduly affectionate, but also fearful in the absence of his usual protectors, and given to excessive anger when he does not have his own way. This attitude is often carried into adulthood, and results in an insufficient individual who always expects parent-like consideration from those about him, and is alternately fearful and enraged when he does not receive it. A moderate degree of affectionate attachment, avoiding the extremes both of cold rejection and of excessive stimulation, is desirable.

The phenomenon of love between the sexes, seen in adolescents and adults, shows more evidence of being a genuine emotional state. The classic lover is distracted and cannot concentrate, his heart beats rapidly upon seeing his loved one, his bosom heaves, and his blood pressure rises. In short, he shows the signs of a first-class case of emotion. The sources

of this condition of romantic love are not clear, but three factors seem to contribute to it. First, the love reactions develop from, and are to some extent patterned after, the affectionate responses of earlier life. Second, the maturing of the sex glands in adolescence stimulates the individual to a healthy intensity of reaction that is readily directed into either primary or substitute sexual activities. Third, the social tradition, gained from books, conversations, motion pictures, and the observation of others, directs the adolescent's love responses into whatever expressions are receiving current social sanction. This third factor, the social or imitative one, is probably the most important. In many societies, romantic love in the modern American and European sense is quite unknown. Marriage in such groups may be entirely a business matter, and sexual behavior is not accompanied by the longings, yearnings, and posturings that pass for "being in love." This social control of love behavior is by no means a bad thing. Some adolescents may act foolishly while "in love." But processes that are very similar psychologically may, in other instances, set up fine ideals for the relationships between the sexes, resulting in the unselfish, mutually tolerant, and helpful partnership that characterizes love in the successful marriage.

Physiological Characteristics of Emotion

The internal or physiological changes are perhaps the most significant part of emotional reactions. An individual has little control over his internal bodily conditions, which are profoundly modified whenever an emotional reaction occurs. Therefore these inner changes constitute the most reliable indication of emotion. The external manifestations of emotion can be imitated by a skilled actor when no real excitement exists. On the other hand, a person with good self-control can appear calm outwardly when he is actually very much aroused internally. Since he cannot entirely inhibit the physiological signs of emotion, these disclose his state.

Circulatory Changes. Emotion involves changes in the rate

of heart beat, in blood pressure, and in the distribution of blood in the body. The change in *heart beat* is most readily observable. It may be noted by counting the pulse rate before and after emotional stimulation, or it may be recorded by more precise instruments. One way of recording heart action is by the *sphygmograph*, a tambour that fits over an artery in the wrist and leads to a device that records the heart beat on a revolving drum.[4] Another more delicate apparatus is the electrocardiograph, an instrument that detects and records the electrical effects of the contractions of the heart muscles. These instruments show that excited emotion has two effects upon heart action. The *speed* of heart beat is increased, and the *amplitude* or strength of each beat is increased in all excited emotional states. There are no fixed patterns of heart action that are different for the various "emotions."

The *blood pressure* also increases in excited emotion. This is measured by the *sphygmomanometer*, which consists of a rubber bag wrapped around the arm and inflated with air, together with an instrument for measuring the air pressure. The air pressure in the bag that is just capable of stopping the circulation of blood in the arm gives the measure of blood pressure. Some investigators have found a more rapid rise in blood pressure in anger and a slower but greater increase in states of fear. These differences are not always present, however, and it is not fruitful to attempt to distinguish various emotions on the basis of blood pressure.

Another circulatory change is in the *blood volume* in the extremities. In emotion the large arteries in the trunk contract, driving blood into the head and limbs and causing a measurable enlargement. The *plethysmograph* is an apparatus for recording this effect. It comprises a cylinder into which the

[4] A *tambour* is a small metal chamber covered on one side with a rubber diaphragm, and having a connection for a rubber tube. Any slight pressure on the rubber diaphragm of the "receiving" tambour is transmitted to the rubber tube as a variation in air pressure. At the other end of the tube is a similar rubber-covered chamber known as a "recording" tambour, whose diaphragm pushes a delicately pivoted lever up and down. This lever may be made to write upon the revolving drum of a *kymograph*. See Figs. 44-46.

forearm is inserted, and which is then filled with water. An increase in the volume of the arm displaces water in the cylinder, which can then be recorded by a tambour (Fig. 44). As a variation of this apparatus, often used in demonstrations of the effects of emotion, a sphygmomanometer sleeve may be wrapped around the arm and inflated lightly with air

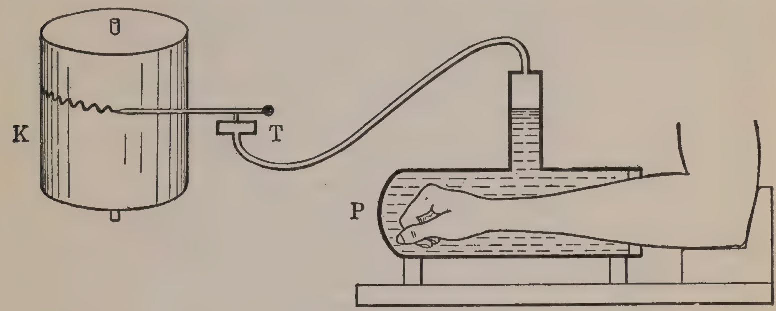


FIG. 44. Plethysmograph.

The subject's arm is inserted in the plethysmograph cylinder (P) which is filled with water. Changes in blood volume in the arm cause displacements of the water, and hence cause changes of the air pressure in the tambour (T). The revolving kymograph drum (K) records the movements of the tambour.

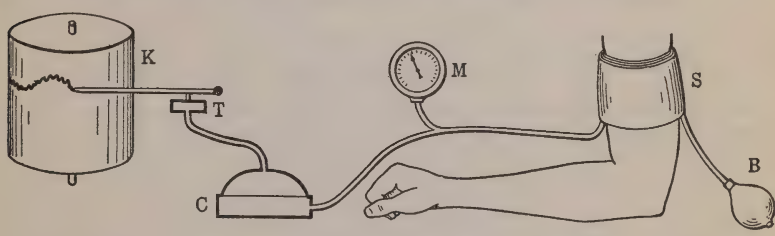


FIG. 45. Recording Sphygmomanometer.

The rubber sleeve (S) is wrapped around the subject's arm and is inflated to 40 to 80 pounds pressure by means of the bulb (B). The total pressure is read on the manometer or pressure gauge (M). The reducing capsule (C), which has a thick rubber diaphragm dividing two air chambers, reduces the pressure to an amount suitable for the delicate tambour (T), which makes a record on the kymograph (K).

(Fig. 45). Changes in arm volume cause variations in the pressure against the bag, and so can be recorded. This apparatus shows the heart beat as well as the blood volume, since each pulsation of blood increases the volume slightly.

Respiratory Changes. It is commonly observed that emotion is accompanied by changes in the rate and depth of breathing. This effect is investigated by means of a *pneumograph* (Fig. 46). A large rubber tube is fitted snugly around the body so that the chest presses against it during inhalation. The pneumograph is connected by an air tube to a tambour that records each inspiration and expiration of air from the lungs. Changes in breathing always occur during strong emotion, but they do not show a consistent pattern. Breathing

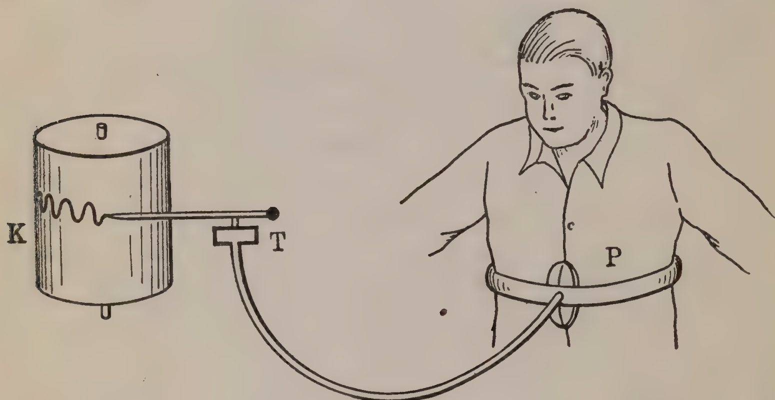


FIG. 46. Pneumograph.

The pneumograph (*P*) is a large, soft rubber tube placed around the subject's chest. When he inhales, the air is forced out of the tube. The breathing record is made by the tambour (*T*) on the kymograph (*K*).

may become more rapid or slower, either deeper or shallower, or more irregular in rhythm.

The best respiratory indicator of emotion is the ratio of the time taken to inhale to the time taken to exhale. This inspiration-expiration ratio (I/E ratio) often increases in states of startle or sudden excitement; that is, inhalation is slower than normal and exhalation is quicker. Several investigators have also shown that the I/E ratio usually increases during the emotion attendant upon telling a lie.

It has also been shown that a person's *oxygen consumption* increases during emotional excitement. Gains of from five to

twenty-five per cent in oxygen metabolism have been noted by various experimenters.

Duct Gland Responses. A large number of the duct glands of the body vary their secretions in response to emotion-provoking stimuli. One of the most interesting of these changes occurs in the sweat glands of the skin, which secrete excessively during strong emotion. It has long been known that a fearful individual develops "a cold sweat" because of this effect.

Very slight emotional changes may be detected by an indirect measurement of the moisture of the skin. As early as 1888 changes in the electrical conductivity of the skin were noticed, and soon afterward these were associated with excitement and emotion. This phenomenon, known as the *galvanic skin response*, is now believed to be due chiefly to the action of the sweat glands, although other mechanisms, such as those for the temperature regulation of the skin, also influence it. To measure the galvanic skin response, two small metal electrodes are placed a short distance apart on the skin, and are connected to any of several devices for measuring electrical resistance. A Wheatstone bridge and a sensitive galvanometer are often used. In general, electrical resistance is lowered during emotion, because moist, sweaty skin conducts electricity more readily than dry skin; but the amount of change is not necessarily proportional to the degree of emotional excitement. The galvanic skin response is not specific to emotion, but also occurs during exercise, voluntary movement, and intense concentration. It is therefore a suggestive, but not a conclusive, evidence of emotion.

Emotion is accompanied by marked changes in the digestive glands. The secretion of saliva and of gastric fluid is inhibited during strong emotions such as anger or fear. The salivary change gives the "dry mouth" feeling often reported after fear. During emotion the saliva usually becomes more alkaline, but this same effect is also produced by exercise or by hard mental work. The inhibition of the gastric secretion is a part

of the total pattern by which emotion interferes with digestion. The digestive movements of the stomach and intestines also stop, and blood is withdrawn from the viscera. These effects have practical importance. Strong emotional states such as rage or fear may interfere sufficiently with digestion to produce discomfort, illness, and even malnutrition, if they persist over a long period of time.

Endocrine Gland Responses. The endocrine glands, which secrete hormones directly into the blood, have a regulatory effect upon many bodily activities, and function continuously under normal conditions. In the emergency state of emotion, certain endocrines secrete excessively and perform an adaptive function in preparing the body for great muscular exertion. Situations in which individuals have shown an abnormal amount of strength under exciting conditions are well known, such as a small man carrying a heavy table from a burning house. Such a display of strength is rare under normal circumstances, but an excessive glandular secretion may help temporarily in meeting the emergency. However, the counteractivity of the bodily processes that brings about recovery from this "automatic drugging" of the body is often unpleasant. After the emotional excitement caused by the fire has worn off, the man who carried the heavy table will feel much fatigued. The fatigue will result not only from the muscular effort, but from the recovery of the general bodily mechanisms to their normal conditions.

The hormone *adrenin,* secreted from the medulla of the adrenal glands into the blood stream, causes a rise in heart action and liberates sugar from the liver into the blood, which supplies the skeletal muscles with quickly available muscular energy. The blood also carries a greater amount of oxygen from the lungs to the muscles and removes waste products. The skeletal muscles are unusually active in most cases of emotional excitement, which means that they fatigue rapidly. Thus adrenin serves to refresh the muscles, enabling the individual to meet the conditions of emergency. Further, in case of

a wound, adrenin hastens blood coagulation. A certain amount of blood that takes five minutes to coagulate under normal conditions will clot in one minute in emotional excitement.

The artificial injection of adrenin directly into the blood stream causes the same physiological disturbances to take place. These are experienced by the subject, but without any true emotional accompaniment. Subjects experimented upon under these conditions report that they feel "keyed up" and ready for some emergency. Landis tells of one subject who termed the experience "feeling like an accident waiting for some place to happen." A part of the general emotional pattern was present, but certain other elements were lacking. Therefore, this artificial situation lacked some of the characteristic patterns of true emotion.

There is no clear-cut experimental evidence to show the exact functions of other endocrine glands in emotion. It is thought that *thyroxin*, a secretion of the thyroid gland, is secreted directly in response to emotional situations. Many people who have goiters, which are caused by an excessive growth of the thyroid, seem to be in a constant state of irritability. Landis suggests that the thyroid secretion sets up a physiological background for emotional responses.

The Significance of Organic Changes. The biological significance of emotion has been formulated by W. B. Cannon in his *emergency theory* of emotion. According to this hypothesis, emotion has survived through the course of evolution because it had an adaptive value in lower and more primitive conditions of life. Emotion prepares the organism for greater strength and endurance of muscular effort in emergency situations that demand struggle or flight. The physiological evidences of emotion that have been described have obvious utility for this purpose. The respiratory and circulatory changes provide additional food and oxygen for the muscles. The inhibition of digestion diverts energy from vegetative processes, making it available for other muscular effort. Most remarkable is the adaptive value of the adrenal secretion,

which reinforces the circulatory changes, provides blood sugar, diminishes fatigue, and even hastens the clotting of blood. It is evident that emotion prepares an animal for an extreme temporary muscular effort.

Under civilized conditions of life emotion has much less utility. While strength may be of greatest value in a blind struggle of tooth and claw, sagacity and thoughtfulness are more useful to man. Emotion prevents clear thinking and carefully planned action, and therefore is unadaptive for man, even in fighting an enemy or in fleeing from danger.

Practical Applications. Since the physiological characteristics of emotion are subject to very little voluntary control, they may be used to discover the presence of slight emotional reactions that would escape detection by any other means. A recent development of this technique is the "lie detector" (Fig. 47). This is a convenient apparatus that makes a continuous record of the principal physiological evidences of emotion. The Darrow polygraph, one of the most widely used "lie detectors," makes a continuous record on photographically sensitized paper of the subject's relative blood pressure, pulse rate, respiration, and galvanic skin response. It also records slight involuntary movements and tensions of both hands by means of *tremographs* upon which the subject rests his fingers. In addition, the record shows the exact instant at which questions are asked and answers given, enabling the measurement of reaction time and the correlation of the verbal with the physiological evidence. Telling an untruth usually causes some slight emotional upset which is shown by increased blood pressure, increased pulse rate, irregular rhythm of breathing, increase in the I/E ratio, decreased skin resistance, tremor or tension of the hands, and delayed reaction time.

The so-called "lie detector" does not really measure lying, of course; it measures emotional upset. Each particular evidence of emotion is not very reliable, but a combination of many evidences is more conclusive. If the subject shows blood, breathing, skin resistance, and hand tremor changes upon being asked

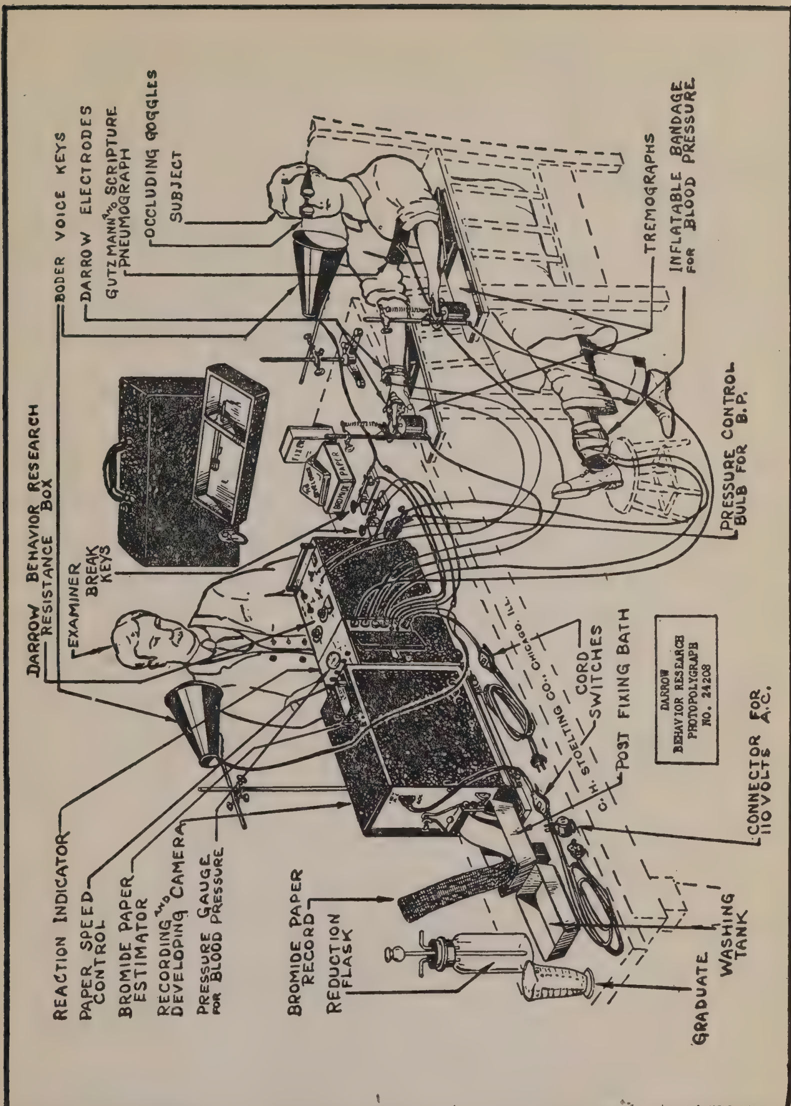


FIG. 47. Darrow Polygraph or "Lie Detector."

The instrument measures and records changes in pulse rate, blood pressure, breathing, galvanic skin response, and tremors of the hands. It is also equipped with voice keys which make a record of the reaction times between questions and answers. All records are made on photographically sensitized paper, which is seen emerging from the left end of the polygraph. (Courtesy of C. H. Stoelting Co.)

a certain question, there is surely something significant about it. There is small likelihood that his general excitement attendant upon being tested will be mistaken for falsehood. Judgments are based upon the differences in physiological evidences between routine questions and certain significant questions. The greatest danger in the interpretation of results is that some questions may persistently arouse emotion even when the answer is truthful. Because of this limitation, the "lie detector" is not an absolutely conclusive evidence of falsehood, and probably never will be.

The "lie detector" is most useful in the preliminary investigation of cases. In one criminal case, an alibi rested upon a witness who said that she had been with the suspect continuously during a two-hour period. This statement evoked evidences from the "lie detector." Confronted by this instrumental indication of lying, the witness broke down and admitted that the suspect had been away from her for a half hour, which time was sufficient to commit the crime. This assisted in obtaining a conviction. The evidence of the "lie detector" is not admitted in court, and probably should not be, but it serves its purposes in the detection of crime and in indicating fruitful directions for further investigation.

The Neural Basis of Emotion

Emotional responses involve almost all the effectors of the body, both skeletal and visceral. Therefore, all parts of the nervous system participate to some degree in the innervation of emotional behavior. Certain neural structures, however, are especially concerned with emotion. These are the *autonomic system*, and a part of the *thalamus*.

The Autonomic System. One of the major divisions of neural structure, the autonomic system, functions particularly in the regulation of the internal organs of the body, as has been described in Chapter III.[5] The cranio-sacral part of the autonomic system maintains the normal operation of the

[5] See pp. 71-73, and Fig. 18.

viscera, and the thoracic-lumbar or *sympathetic* portion conveys impulses that arouse emergency reactions. Sympathetic innervation causes an increase in heart rate and respiration, a constriction of the visceral arteries, and an inhibition of digestive movements and secretions. The adrenal glands are connected to the sympathetic division and secrete when stimulated through it. The sympathetic also activates the tear and sweat glands, and inhibits the salivary glands. It is evident, therefore, that the responses innervated through the sympathetic division are identical with the physiological evidences of emotion that have just been described. In fact, there is no doubt that the inner emotional reactions operate through the sympathetic division. If the connections of the thoracic-lumbar ganglia of an animal are severed by means of an operation, it no longer shows visceral reactions to emotion-arousing stimuli. The sympathetic division is rather loosely organized and acts as a whole, which explains why all the physiological evidences of emotion occur together. It is also slow to be aroused, persistent when once set off, and relatively free from voluntary control.

The Thalamus and Cortex. The impulses that are distributed to the visceral organs by the sympathetic system originate, of course, somewhere in the central nervous system. A number of lines of investigation have located the emotional region of the central nervous system in a part of the *thalamus*. This lower brain structure acts principally as a relay station for sensory impulses between the sense organs and the cerebral cortex. Another part of the thalamus, however, contains the centers for visceral adjustment that are connected through spinal pathways to the sympathetic division of the autonomic system. The impulses from the thalamus serve to set off the visceral components of emotion, and also to control them to some extent.

The general bodily reactions which make up such an important part of emotional behavior would be excessive and out of control were it not for the inhibitory functions of both the thalamus and the cerebral cortex. The cerebral cortex acts,

as it were, as a first-line defense against the overactivity of emotional reaction. Many experimental studies on animals, and observations on human subjects who have injuries of the cerebral cortex, show extreme emotional responses to stimulus situations that would not otherwise arouse such reactions. For example, when a normal dog is pinched lightly on the side there is little evidence of disturbance. He usually does no more than turn his head lazily to see what is going on, and gives no exhibition of being emotionally upset. But when the cerebral cortex of a dog has been removed by an operation, emotional behavior is very easily aroused. In response to a mild pinching stimulus the animal will make an energetic intervention by growling and biting at the place stimulated. This emotional reaction, which might be labeled rage, is stereotyped in pattern and not well under control. The dog will bite at the stimulated area, even sinking his teeth into his own flesh. Human beings who lack higher cortical control because of an injury to the brain or because of a congenital feebleminded condition, show a deficiency of emotional control. Such persons may become violent on many occasions to which the normal individual would pay little attention. Thus, besides being a center for the higher perceptual processes and voluntary reactions, the cerebral cortex acts as a *partial inhibitor* for emotional reaction.

The importance of cortico-thalamic control of emotion, that is, the mutual inhibitory effects produced by an interaction between the cortex and the thalamus, can be seen from certain studies of persons suffering from brain injuries. Subjects with unilateral lesions (on one side) of the thalamus have a tendency to react excessively to all potentially emotional stimuli. Since the thalamus is a relay station for sensory impulses going to the cerebral cortex, any injury that cuts the connections between the cortex and thalamus induces an excessive emotional response. That is, sensory impulses which are normally transmitted to the cortex and there integrated with impulses that serve to elicit motor reactions now become organized

with motor impulses at the thalamic level. The elimination of the inhibitory influence of the cortex causes excessive emotional reactions and feelings. Therefore many stimuli that would be agreeable under normal conditions become keenly unpleasant when applied to the side of the body affected by the thalamic lesion. A pin prick that ordinarily might be disregarded by a normal person may arouse extreme emotional behavior on the part of an individual with a thalamic injury. One case which has been described (Head, 1920) is that of a woman who before her illness was very appreciative of certain kinds of music which stirred pleasant feelings. After a unilateral lesion in the thalamus had occurred she no longer received pleasant experiences from music, but rather had disturbing sensations over the afflicted side of the body. These facts show that the thalamus acts as the center of emotional organization and operates with the cortical centers in maintaining the normal emotional life of the individual.

Emotion as Consciousness

So far we have dealt with emotion as a form of overt response, and as a pattern of inner changes. One further problem of emotion remains, that of emotion as consciousness or awareness. Two principal theories have been proposed to account for the peculiar "state of mind" that accompanies emotion.

The James-Lange Theory. One explanation of the conscious side of emotion was advanced almost simultaneously by two persons, the American psychologist William James and the Danish physiologist C. G. Lange. The James-Lange theory states that the emotional experience consists of an awareness of the organic changes that are in progress. The visceral responses follow the perception of the stimulus quite directly. The peculiar "feel" of emotion comes from the sensations arising from the viscera; from the consciousness that the heart *is* beating faster, that digestion *has* stopped, and so forth. This theory was a landmark in the development of objective

psychology, for it did away with the assumption that consciousness had to precede overt action. According to this theory the sequence is

stimulus ⟶ bodily response ⟶ awareness

and not:

stimulus ⟶ awareness ⟶ bodily response

Many early supporters of the James-Lange theory asserted that the *only* consciousness of emotion came from the viscera. This exaggerated stand has not been substantiated by the experimental results obtained subsequently. A few cases have been observed of persons who, because of spinal cord injury, have no sensations from their bodies. These individuals report a consciousness of emotion under appropriate stimulation even when visceral sensations are impossible. Such evidence suggests that brain centers may mediate an emotional experience even without an awareness of organic processes.

Cannon's Thalamic Theory. One of the strongest opponents of the James-Lange theory has been W. B. Cannon, who has proposed that the consciousness of emotion is a function of the thalamus. According to this point of view, the entering sensory impulses that inform the individual of the exciting situation enter the thalamus where they immediately set up a crude, vague kind of consciousness. The pattern of impulses determined by the thalamus is also transmitted to the cerebral cortex, determining the finer aspects of the experience, and to the autonomic system through whose agency they cause the bodily changes. In contrast to the James-Lange theory, the Cannon theory may perhaps be indicated as

$$\begin{tikzcd} & \text{awareness} \\ \text{stimulus} \arrow[ur] \arrow[dr] & \\ & \text{bodily response} \end{tikzcd}$$

That is, the awareness is not subsequent to the bodily response, but is simultaneous with it and relatively independent of it. The thalamic theory is supported by the evidence concerning the rôle of the thalamus in emotion that has already been presented.

A Synthesis of Theories. There is probably some truth in both the James-Lange and Cannon theories, and they are not necessarily contradictory. The complex experience of emotion comes from more than one source. Three principal origins of the awareness of emotion may be noted. First, the intellectual perception of the stimulus situation has much to do with the nature of the emotional experience, especially in adult human beings. It has already been stated that fear and anger are better distinguished in terms of the situations that cause them than in terms of the responses they evoke. The individual's understanding of the situation, and his prospective adjustment to it, are therefore very important determiners of what "emotion" he will feel. Second, as emphasized by the Cannon theory, a vague and unlocalized "stirred-up" state of consciousness is characteristic of emotion. This is quite probably due to the action of the thalamus. Third, the James-Lange theory undoubtedly holds to some extent for normal human adults, notwithstanding the objections to it. The pounding heart, the panting breast, and the dry mouth are important components of the conscious experience of fear. All three interpretations of emotion are necessary for the complete understanding of it as a condition of awareness.

The Control of Emotion

The desirability of controlling emotional reactions is recognized by all students of human affairs. As has been stressed throughout this chapter, emotion is a disorganized response that hinders an individual from making effective adjustments. Although the way to emotional control is not direct and simple, several helpful suggestions can be made. First, some control of emotion can be achieved by controlling its outward mani-

festations. An individual who maintains an appearance of calmness in the face of stimuli that provoke fear or rage has taken the first step toward real calmness. This is true because the various features of an emotional reaction tend to reinforce each other. If one flees with fear or rages with anger, the overt behavior makes the visceral responses more intense and therefore makes the total emotion greater. On the contrary, control of one's actions, manner, and speech so as not to reveal the emotional states, helps to inhibit the visceral responses. Some nonsense has been written about the harm done by "repressing one's emotions." Probably more harm has been caused by uncontrolled emotional reactions than by any reasonable attempts to control them.

A second and more fundamental way to control emotion is by becoming adjusted to the stimulus that produces it. Since emotion is a nonadjustive reaction, all procedures that give an individual greater adjustive power over his environment will lessen emotional reactions. While emotion inhibits clear thinking, fortunately it is also true that clear thinking inhibits emotion. A situation becomes less fearful when its nature is investigated intelligently. Anger can be greatly modified by searching for a rational way to overcome the obstruction, or by examining the motives and character of the person who stands in one's way. Intellectual responses to situations perhaps represent the cortical inhibition of crude thalamic activity, and thus control emotion in a way that can be understood physiologically. The reason that more people do not have emotional control is probably that they do not want it. A person who secures his ends by angry blustering, or who gains sympathy by being fearful, will not readily overcome these habits. The control of emotion will not be obtained by mere wishing, but can be achieved through the use of principles basic to all habit formation, such as motivation, practice, and success.

Chapter VII

MOTIVATED AND VOLUNTARY BEHAVIOR

The analysis of human behavior would be incomplete without an account of the many situations in which individuals *wish, desire, will,* and *choose.* Human beings not only display reflexes, habits, emotions, and the other forms of behavior that have been described in the preceding chapters, but they also perform many acts "voluntarily" or because they "want" to do so. To explain these activities is one of psychology's most difficult tasks. There are many false and misleading popular beliefs about "the will" which must be removed before a sound psychological approach can be made. Moreover, the acts that common opinion ascribes to "will" are not all of one sort, but must be interpreted in terms of at least three lines of psychological investigation. "Wishing" and "wanting" define the problem of *motivation*, which is the study of the dynamics of behavior, or what it is that makes an organism move and strive. Doing an act because one "wills" to do so defines the problem of *self-initiated action*, or the responses to stimuli that seem to come from within oneself instead of from the outer world. Finally, some of the more complex problems involved in the popular conception of "will power" require an investigation of the psychology of *discrimination* or *choice*, the processes that distinguish an individual's behavior when he is confronted with more than one possibility for action. These three lines of inquiry will be discussed in the present chapter.

Motivation

Human beings want many things. Their simpler wants, including those for air, drink, food, shelter, and the like, arise

from bodily needs and are induced by stimuli from within their bodies. These desires are popularly referred to the individual himself rather than to external circumstances. One says, "*I* want my lunch" or "*I* want to go to sleep." This common conception of motive is in a large measure correct, for the needs originate from intra-organic stimuli.

External events also have important functions in motivation, however. In addition to his bodily needs, man wants to run away from danger, to overcome obstacles, to obtain a mate, and to receive praise and avoid scorn. These motives are set off by stimuli from outside the body. Much more complex are the motives to do good to one's fellow men, to attain leadership in a field of science, or to create a great work of art. Even these complicated varieties of behavior can be understood, however, if we know enough about the composition and history of the individual who engages in them.

An analysis of motivated behavior involves all the elements of the formula $S \longrightarrow O \longrightarrow R$. Motivated behavior is evoked by certain *stimuli* that are known as drives. A *drive* is a *strong, persistent* stimulus that *demands an adjustive response*. The most important drives are bodily stimuli, that is, interoceptive and proprioceptive ones. These initiate some of the simpler forms of motivated action directly, and reinforce the more complex types of motivation.

What kind of response a drive will call forth depends upon the nature of the *organism*. The species of the animal, its degree of maturity, its physiological condition, and especially what it has learned, determine what kind of behavior a given stimulus will evoke. The entire pattern of motivated behavior, therefore, depends as much upon the organism as upon the stimulating conditions.

A motivated sequence of activity is brought to an end by an adjusting or completing *response*, which has the effect of abolishing or reducing the drive. The motivation to eat, for example, is evoked by the drive of hunger, carried out by the habits typical of the animal concerned, and concluded when the presence of food in the stomach causes the drive stimulus

to cease. A *motive* may now be defined as a tendency to activity, initiated by a *drive* and concluded by an *adjustment*. The adjustment is said to *satisfy* the motive, that is, to fulfill the conditions imposed by the situation and the organism.

Stimuli as Fundamental Drives. The most fundamental drives originate from the bodily needs of the individual. An example of such a drive, upon which many experiments have been performed, is hunger. Hunger results from a deficiency of food nutrients in the body which in turn excites rhythmic contractions of the stomach. These contractions can be observed by having a subject swallow a stomach balloon which permits the time and extent of the contractions to be observed and recorded. Research with this apparatus indicates that the "pangs" of hunger that one feels subjectively are sensory reports of the stomach contractions. These internal stimuli arouse general activity. When a subject lies on a bed that records all his motions, periods of greater movement coincide with periods of stomach contraction, whether he is asleep or awake. It has also been found that persons can exert a greater strength of grip and even get higher scores on intelligence tests while stomach contractions are occurring. In these instances the internal stimuli reinforce the other activities.

The native responses to stimuli such as hunger are diffuse and nonspecific. The infant becomes active-all-over when affected by a drive stimulus because he has not yet learned any definite forms of adaptive behavior. All strong internal stimuli produce the same diffused type of response. Experiments have shown that observers cannot distinguish the reactions that infants make to such diverse stimuli as hunger, restraint, dropping, or pain. These observations point to the important principle that the basic drives natively excite only mass or random activity. Later, when the individual has learned how to satisfy his motives, various stimuli may arouse appropriate habits of adjustment.

Learning modifies motivated behavior in two principal ways. First, the individual learns *habits of response* that tend to

satisfy his needs. The hungry dog learns to "beg" at the kitchen, to scratch at the door, or to roam about the alleys. Human beings learn to wait until mealtime, to ask for food, to purchase it, or to prepare it. All these responses are habits acquired through learning. A second modification of motives occurs by a *change in the stimuli* that will elicit the behavior in question. Originally hunger is aroused only by a nutritional deficiency. Later, the sight or smell of food will arouse hunger pangs and their resultant urge to eat, and even talking about food may activate the urge. It is important to note that drive stimuli natively arouse behavior-in-general. Specific adaptive responses are all learned.

Hunger is not the only example of a drive originating from an internal bodily need. Other similar motives include air needs, thirst, temperature regulation, elimination, and certain basic glandular aspects of sex motivation. Each of these has a definite internal stimulus, initially arouses random adjustive activity, and finally is satisfied by an appropriate learned response habit.

Certain external stimuli excite motivated behavior very similar to that elicited by internal stimuli. Stimuli that cut, prick, burn, or bruise may be grouped together as *tissue injury* stimulations. Adjustments to these stimuli serve bodily needs that are as basic as hunger or thirst. Tissue injuries natively arouse only strong general or random behavior. The infant writhes and squirms when stimulated by injuries to his skin, but does not make avoidance movements natively. Later, when the child has learned to do so, painful and injurious stimuli provoke definite and skillful movements of withdrawal. A further step in learning is the avoidance of imminent injury or danger. Through processes of conditioning, the child learns to avoid an injury before any painful stimulation has occurred. Adjustments to the external stimuli show the same process of development as do the adjustments to the internal drives. With increasing experience, the responses become more definite, adaptive, and useful.

The Measurement of Motives. The relative strength of some of the simpler motives has been measured for several lower mammals, especially complete studies having been made on the white rat. The most successful way to measure these motives is the *obstruction method* devised by Moss, and modified by Warden (Fig. 48). The obstruction apparatus consists essentially of three compartments. The animal is placed in the first compartment, and the incentive in the third, separated from the animal by a grid which administers an electric shock. The shock is held at a constant value, and the strength of the

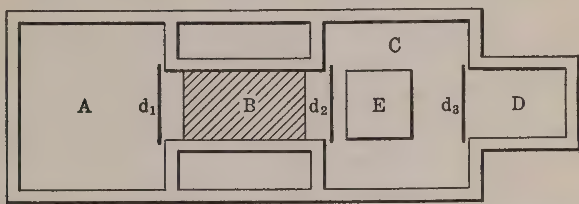


FIG. 48. Obstruction Apparatus for Measuring the Strength of Motives in Animals.

The animal is released from compartment *A* by opening doors d_1 and d_2. He must cross the electric grid *B* in order to reach the release plate *E* that opens door d_3, enabling him to reach the incentive (food, water, etc.) placed in compartment *D*. (From C. J. Warden, *Animal Motivation,* Columbia University Press.)

motive is measured by the number of times that the animal will cross the grid during a twenty-minute period. To investigate the strength of the hunger drive, food was placed in the incentive compartment, and rats that had not eaten for various periods of time were released in the first compartment. Thirst, sex, maternal, and exploratory motives were investigated in a similar way. While each motive was being studied, all the others were kept at a minimum strength.

The relative strengths of the various drives of the white rat may be expressed in terms of the average number of crossings of the grid. The maternal drive was the strongest, eliciting 22 crossings. Thirst caused an average of 20; hunger, 18; the female sex drive, 14; the male sex drive, 13; and the explora-

tory urge, 6. The motives of human beings cannot be measured so directly, and have not been investigated satisfactorily. It seems probable that the more complex social motives are stronger in most people than the simple physiological drives.

Emotion and Motivation. The consideration of internal states as drives inevitably suggests that *emotion* must be of some significance in motivation, since emotion consists of an intensely stirred-up visceral condition. In fact, emotional responses are basic to many important forms of motivation. Emotion is especially pertinent because of its strength and persistence, and because it can be conditioned to such a variety of situations. An external stimulus has to be rather intense in order to serve directly as a drive. But if this environmental situation sets up an emotional response, the internal state of the emotion in turn serves as a stimulus, arousing strong and persistent tendencies to behavior.

Any original or conditioned stimulus that will provoke a rage response will result in strong motivation, which, in a developed form, is directed toward overcoming the person or obstacle that aroused the rage. Similarly, fear sets up a strongly motivated avoidance. The emotional state in these instances is a connecting link between the external situation and the motivated response. The outer stimulus may soon disappear, but if it has set up an emotional visceral state this inner condition acts as a continuing stimulus to excite further responses. This sequence accounts for some of the lasting effects of emotion, some of which are socially desirable and some not. Persistence, ambition, rivalry, and cooperation are motivated to a large extent by emotion, as are also stubbornness, moodiness, or fearfulness. The way in which emotion is basic to a number of social motives is considered a little later.

Positive Motivation. The simple drives that have been described thus far are "annoying" stimuli that the individual wants to get rid of or get away from. Each of these stimuli, whether an inner drive such as hunger, or an outer one as in

the case of pain, arouses responses that tend to continue until the stimulus is removed. These motives lend themselves nicely to the $S \longrightarrow R$ scheme of behavior, for when the stimulus is eliminated it no longer arouses a response, and the activity ends.

Another general class of drives exists, however, which arouses a response that tends to reinforce the stimuli rather than to remove them. Such stimuli are popularly said to give pleasure for their own sake, and not merely because they represent the avoidance of an annoying state of affairs. But it must be recognized that these stimuli are not explained adequately by calling them pleasant, since the chief evidence of their pleasantness is the fact that organisms seek them rather than avoid them. In general, individuals respond positively, or by approach, to bright objects, sweet tastes, flowery odors, or a gentle stroking of the skin. The opposite stimuli of sour or bitter tastes, foul odors, or harsh scratching are usually avoided. The term *positive drives* may be applied, therefore, to stimuli that call forth the seeking, approaching, or continuing responses. *Positive motives* are the corresponding tendencies to behavior.

Positive motives are closely allied to the emotional responses of delight and affection. Fondling, petting, and gentle stroking evoke from infants a response of a positive nature which invites a continuation of the stimulus. When a child becomes accustomed to attention of this type he seeks the stimulation actively, and so learns to want the company of persons who minister to his satisfaction. In this way the primitive types of positive motivation lead to the development of social motives.

The positive and annoying types of motives are mutually interdependent. The avoidance of one stimulus almost always involves the seeking of some other situation. Hunger, for example, is not only the avoidance of an annoying inner condition, but also a positive approaching tendency toward food. From the other side, the denial of an accustomed satisfaction is a definite annoyance, and often results in strongly motivated

behavior. In an original unlearned condition all motives relate to the state of the organism. By learning, the avoidance of a bodily deficiency becomes a positive tendency toward anything that will satisfy the need. The maintenance of a bodily satisfaction also becomes equivalent to an avoidance of whatever might prevent it. In this manner, motivated behavior comes to be evoked by persons and things, and the operations of positive and negative motivated tendencies become inseparable.

The Development of Social Motives. In addition to the motives relating directly to bodily needs, human beings engage in many forms of motivated behavior in their contacts with one another. A number of social motives in man were formerly believed to be native or inherent in the species. They were termed "instincts," and included forms of behavior such as desiring approval, avoiding criticism, seeking companionship, and the like. Modern psychologists agree that these motives are not instinctive, but are learned principally by modifications of the motives relating to organic needs.

It is unnecessary and futile to try to list all the social motives of mankind. It is even somewhat dangerous to do so, since motives that are named may be mistaken for "inner forces" that compel the person to act as he does. No such forces exist, of course, except the visceral stimuli of the simpler drives and the patterns of the nervous system that operate more complex habits. Some samples of typical and strong human social motives may be mentioned, however. Men have a marked tendency to seek *preeminence* or *mastery* by trying to succeed in tasks once begun, by getting ahead of rivals, and by overcoming obstructions. There is also a strong motivation toward a certain degree of *conformity*—to do the expected thing, to dress as others do, and not to appear too distinctive or different from one's fellows. Another important type of social motivation is to secure *approval, prestige,* or *recognition* from other persons. Related to the last is the need for *security*, or the feeling that one is safe for the future. The origins of a few

of these motives will be traced in order to show how they are learned by each individual.

The motive pattern called *preeminence* or *mastery* is a strong and dependable human trait. Men seek to excel, to succeed, to overcome obstructions, and to master conditions. The great satisfaction that follows winning a game or completing a challenging task reflects this type of motivation. It is probable that mastery motives originate from the *rage* behavior shown in infancy. When restrained or hampered in movement, an infant struggles violently and shows evidence of the visceral effects of emotion. Mastery behavior develops from this pattern by means of both stimulus learning and response modification. The rage behavior becomes conditioned to many stimuli other than those that provoked it originally. Words and actions of other people come to symbolize restraint. Even the presence of another person who is performing the same task may become a substitute stimulus for a mild degree of this response, as a potential restrainer of action. This tendency is undoubtedly reinforced by verbal learning, since most children are exhorted to do their best and to excel others. Fortunately, the rage response also is modified by other learning processes that occur at the same time. A child learns that mere screaming and kicking will not overcome obstacles, and therefore discovers more adaptive problem-solving activities into which the energy of the emotional response is directed. Although the work of the scientist struggling with a problem may seem remote from the childish tantrum, the motivation is basically the same. A substitute stimulus arouses a visceral state, which in turn stimulates persistent and strong activity which may be directed toward a useful end.

The tendencies to *like to be with people*, to *seek approval*, and to *desire sympathy* have a similar history. They are derived from the *positive motives* previously described and from the satisfaction of organic needs. An infant is helpless and has to receive all his satisfactions from the ministrations of other persons. By the age of four months the child will

smile on *seeing* the mother or nurse, before any food or other bodily attention has been given. This indicates that the process of conditioning has begun. Since kind words and praise are given simultaneously with care and petting, they become positive stimuli and the individual now seeks them. In this manner value becomes attached to approval and praise. A moderate development of social motivation is the most desirable course. A person who is too little influenced by social approval may become antisocial. On the other hand, one who has learned to place too much dependence on praise and approbation may lack originality and initiative and may always be concerned with doing the "right" or conventional thing.

The number of social motivations is large, and it is repetitious to give a detailed account of all of them. The tendency to *yield* and conform is probably based on fear-training early in life. The desire for *security* has a history similar to that of social approval, coming from the original needs for care in childhood. Motives to *acquire possessions*, although common, are very mixed, having elements of security, social approval, and mastery blended into a particular reaction pattern. All such social motives are complex habits, but all are founded on the simpler organic needs, the emotional reactions and the positive responses, which are the basic urges to activity.

Social Facilitation. The presence of other persons has a significant, though variable, influence upon the motivation of an individual. What that influence is depends on the nature of the social situation; it is different when the other persons are observers, co-workers, or competitors. The competitive situation has been investigated most fully. The almost universal conclusion is that persons work harder and faster when competing with others than when working alone. One experimenter found that boys exerted a 12 per cent greater strength of grip, as measured by a dynamometer, when competing with a single antagonist than when alone. Boys working competitively in self-chosen teams of five showed an improvement

of 16 per cent. These results may be ascribed to the arousal of motives of the preeminence or mastery types. In the performance of mental tasks, such as multiplication and the completion of analogies, the presence of competitors increases the speed of work, but usually lowers the accuracy. In some cases, however, rivalry has been found to decrease performance rather than to increase it. An analysis of the causes operating in these instances shows that the individual has been overstimulated by the situation, and tries so hard that he becomes aroused emotionally and loses precise control.

Whether the presence of co-workers without a competitive attitude always increases motivation is uncertain, because experiments have not given consistent results. One very careful study showed that pieceworkers making canvas shoes produced about 10 per cent more when working in cooperative groups of six than when working individually. Here there was no competition, but each worker seemed to be stimulated by the activity of the others. In bicycle racing, as much as 25 per cent greater speed is induced by having the racers paced by a motorcycle. Here the sight of the faster vehicle ahead stimulates the rider more than does the ordinary type of competition with his equals. The enhancement of performance by the presence of co-workers is termed *social facilitation.* It is one basis of *esprit de corps* and other evidences of group morale.

One type of social facilitation that has aroused much interest is the behavior of audiences, crowds, and mobs. It has been shown experimentally that a person is more likely to laugh when others laugh, or to cheer when others cheer. It has also been alleged that crowds and mobs are motivated irrationally when they flee, loot, destroy, or lynch. An old but now discarded explanation attributed crowd phenomena to a "group mind" that was supposed to be an entity in itself. This notion must be rejected on the ground that the only "minds" in a crowd are those of the individuals that compose it. The behavior of crowds can be accounted for in terms of

some of the factors that evoke the behavior of the individuals in it. First, groups ordinarily assemble with a *common motivation*: the theater audience gathers to be amused; the strikers come together to express an industrial grievance. Each individual therefore wants what the others want. Second, the members of a crowd are in a *common situation*; what is visible or audible to one is perceptible to all. With like motivation and stimulation, it is but to be expected that the individuals in a crowd will act alike. Third, *social facilitation* enhances the reactions of each person. In the company of others of similar intention, each person acts like himself, only more intensely so. Spatial density is an important factor in mob behavior, for the more closely crowded the persons are the greater is the facilitation of their responses. It has been shown that an audience that fills a small hall will laugh, cheer, or applaud more than will an equal number of people scattered over a large auditorium. This happens because in a dense crowd more persons are close enough to one individual to stimulate him socially.

A fourth reason for mob behavior of a destructive sort seems the most important. Most persons refrain from engaging in violent or conspicuous acts because of their training to respect the *social approval* of the group. Children are taught not to destroy property or to injure persons, and this habit persists with great strength. In the destructive mob, each individual perceives the intent of the others, and feels that social approval is on the side of the violent act. The group present at the time, especially if it is large enough, determines the social approval factor. Therefore the violence seems to have the support of a section of society, and this fact inhibits the operation of customary habits of conduct.

"Higher" Motives. Human beings also act in a number of ways that are often ascribed to "higher" motives because they are superior ethically. These include tendencies to sacrifice for one's family and for others, to pursue truth or scientific inquiry in spite of adversity, and to do good or to abstain

from doing wrong even when others will not know of the act. These are very complex forms of behavior and cannot always be described in simple terms, but they conform to ordinary psychological laws of learning and development.

As an illustration of "higher" motivation, an attempt will be made to explain "conscience," or the performance of socially approved acts without social pressure. The development of social approval motivation, which makes an individual desire to gain the high regard of his fellows, has been traced. When this habit is well established the performance of unsocial or unethical acts is annoying to the individual because it prevents him from attaining the proper esteem of others. This habit is now ready to serve as the basis for another habit. Since unethical acts are associated with unfavorable results, they become unsatisfying in themselves by a process of conditioning. The person so conditioned finds it hard to do an unethical act even in private, because of the training that he has received. "Conscience" is thus no "inner voice," but is a feeling of dissatisfaction resulting from the second stage of a series of conditionings. It is hard to define the best conditions for the inculcation of these desirable habits. Some research indicates that formal "character training" in schools or Sunday schools is not very effective, but that direct home influences have the greatest value. Because the exact experiences underlying ethical motives are hard to identify, the "good" or "bad" traits sometimes seem to crop out in unexpected surroundings. If a person of good character seems to come from an apparently "bad" family, or a poor one from a supposedly "good" home, it is because subtle and unobserved influences have been at work. Ethical motives are habits, and their development conforms to the psychological conditions of learning.

Self-initiated Action

"Ideomotor" Activity. A very simple and common kind of voluntary action occurs when an individual performs a motor

act in response to a "thought" or "idea." For example, a person may think of raising his hand and immediately do so. This *ideomotor* action used to be contrasted with sensory-motor activity in which a movement is evoked by a sensory stimulus. Modern psychology, however, does not separate these two processes widely. If a person raises his hand "voluntarily" it is pertinent to inquire why he did not instead stamp his foot, turn his head, or lift his eyebrows. On investigation it always appears that some present or immediately past situation was the real determiner of the voluntary act. The external situation arouses the thought, and the thought in turn arouses the final motor activity. The idea or thought is therefore an intermediate step between the sensory stimulus and the motor reaction. It is a valuable intermediate stage because its presence makes possible a more precise control of complex processes of behavior.

The Nature of Symbols. In order to understand ideomotor activity it is necessary to investigate the nature of ideas or thoughts in relation to total behavior. An idea or thought may be described more precisely as a *symbol.* A symbol is an event that represents or stands for something beyond itself. Symbols have been met in a number of experiments already described in the preceding chapters. In the conditioned reaction experiments, for example, the dog lifts its foot when it hears the sound; hence the sound is a symbol for the shock, a substitute stimulus that evokes the behavior originally aroused only by the shock itself. Whenever an individual responds, in the absence of the original stimulus, we may be sure that he is responding to a symbol. Language is a rich collection of symbols, each word standing for some thing, action, or relationship. These are examples of *symbolic stimuli* that are capable of evoking appropriate adjustive responses.

Symbols also may serve as substitute *responses.* A shrug of the shoulders, a nod of the head, a facial expression, or a posture or attitude may represent a person's reaction to a total situation. These symbolic responses are incipient or

partial movements that may take the place of more completely expressed patterns of behavior. They enter into "thought" or consciousness in an interesting and subtle manner. The extent of movement may be so slight that the individual is not aware of it *as a movement*. Instead, he is aware only of a *thought* of the movement, not realizing that his so-called thought actually is a slight movement itself.

The existence of incipient movements in "ideas" is indicated by experimental evidence. When one thinks of a situation he makes slight muscular movements appropriate to the situation. If a person is blindfolded, for example, and told to think of falling forward, he may report that he had the "idea" but that he knows of having made no actual movement. But a delicate indicating device attached to his body shows that when he thought of falling he really did lean forward slightly, even though he did not realize that he was doing so. Similarly, when a person thinks of a word, small incipient movements of the larynx can be detected by precise instruments. Further evidence comes from the study of electrical *action currents* that indicate small movements of muscles. Davis (1938) found that while subjects solved problems in mental arithmetic without writing or speaking, muscular tensions increased in the neck and forearm. The more difficult the problem, the greater was the evidence of muscular activity. All these experiments show that an "idea" may really be an act, and that the consciousness of the idea is the awareness of the act.

Some psychologists believe that this explanation of ideas as incipient movements is sufficient, and that all thoughts have this bodily basis. Others consider that a thought may be a purely neural pattern without always having a muscular expression. According to this second view, a sensory stimulus arouses the activity of a certain set of neurons, and this activity is the state of awareness. This pattern of neural impulses is then communicated to other channels and arouses muscular action. According to either view, a symbol or idea is a real bodily

occurrence, neural or muscular, and is a response to some sensory stimulus.

The concepts of symbols as stimuli and of symbols as responses now lead directly to an explanation of ideomotor activity. The *same* symbol may be a response to a situation and also a stimulus for some further activity. A response to an "idea" is therefore a chain reaction of this type:

$$\underset{\text{(external)}}{S_1} \longrightarrow \underset{\text{(symbol or idea)}}{R_1 = S_2} \longrightarrow \underset{\text{(overt act)}}{R_2}$$

An external situation (S_1) makes the individual "think of something" (R_1), which thought or symbol is itself the stimulus (S_2) for the final motor response (R_2). Ideas or symbols therefore are not spontaneous events or will-o'-the-wisps from some mysterious realm of "mind." They are bodily responses to stimuli, and are in turn stimuli for other responses.

Learning to Respond to Symbols. There are no native or inherent responses to ideas or symbols; all such responses are learned. The infant has no original voluntary control of his activity, but acquires it gradually through practice. By the age of one year, a child will reach for an object that he cannot see, showing the presence of a response to an inner substitute stimulus, or an ideomotor activity. In adulthood all persons with intact bodies have gross voluntary control of all their principal skeletal muscles; but some people, such as athletes, skilled workers, and singers, have an exceptionally good voluntary control of certain muscle groups involved in their particular skill. There are some movements that are acquired by one person but not by another. Some people can wiggle their ears, while others cannot. Finally, there are many movements that almost no one can control voluntarily, such as the beat of the heart or the dilation of the pupils of the eyes.

The way in which voluntary control is acquired is revealed by experiments in which persons have been trained to make responses voluntarily that are not ordinarily subject to such control. In one study of this sort, Menzies (1937) conditioned

a very obscure vasomotor response to "inner" stimuli. When one hand is plunged into cold water the small arteries of the other hand also contract, lowering its temperature. Using the conditioning procedure described in Chapter V, Menzies stimulated the subject's hand with cold water and simultaneously gave certain other stimuli. After repeated trials, the temperature response of the contralateral hand was conditioned to the sound of a buzzer, to a word spoken by the experimenter, to one whispered by the subject himself, to a visual signal of an illuminated cross, and finally to the subject's visual image of the cross. Thus the subject, after this conditioning, could whisper a word or think of a visual image, and the temperature of his hand would decrease! He thus obtained *voluntary control* of this vasomotor reaction and was able to change it "at will" just by thinking of the right stimulus symbol.

Other experimenters have conditioned the galvanic skin response, an emotional response described in the preceding chapter, to words and "thoughts" of the subject. Hudgins (1933) seems to have conditioned the pupillary reflex of the eye to self-initiated stimuli, although this particular result has not been confirmed adequately by subsequent experiments.

It is very probable that the voluntary control of all movements is acquired by each individual in the course of his development by processes essentially the same as those used in the laboratory experiments. Each movement that a person makes is accompanied by an awareness of the act, arising chiefly from the proprioceptive stimuli from the muscles involved. It is also connected to verbal signals for the act, and to various images and thoughts relating to it. These symbols occur simultaneously with the act on a large number of occasions, and therefore become associated or conditioned stimuli that will evoke it at a future time. Everyone thus conditions himself to make the response when the appropriate thought occurs.

The manner in which a thought can stimulate an act now becomes clear. In this lies the answer to the question that

began this discussion, as to how a person can raise his hand when he "wills" to do so. Some situation evokes the thought or symbol of raising the hand. This thought is itself a response in the form of an incipient movement or a central neural pattern. Then, because of past conditioning, the thought can serve as a stimulus for the act that is performed.

Discriminating Between Courses of Action

Individuals are often stimulated by more than one motive at a time, and under circumstances such that all the motives cannot be satisfied. Let us suppose that while a person is reading an interesting book a friend telephones to invite him to see a motion picture. Two kinds of satisfaction conflict in this situation, for he cannot read the book and go to the motion picture at the same time. He has to make a decision or choice, selecting one satisfaction and foregoing or postponing the other.

A special case of conflict between motives has long been of great popular interest. Instead of deciding between two pleasures as in the instance cited, an individual may have to decide between a pleasure and a "duty." If he is studying a dull and uninteresting academic assignment when the invitation to go to the motion pictures arrives, the choice seems to be of a somewhat different sort. A decision to continue the study is usually regarded as an act of strong "will power." On the other hand, to neglect the necessary school work for the sake of mere amusement is taken as evidence of a "weak will" and is regarded as a personally and socially inferior type of choice. "Will," however, is only a word that describes the choice that is made. "The will" is not an organ or faculty of the individual, but is a way of behaving with respect to choices. The duty of psychology is to determine what really occurs when "will power" is shown, and to investigate the conditions underlying the choosing of courses of action.

Ethical and Psychological Aspects of Will. It is important at the outset to distinguish between the ethical and the psy-

chological interpretations of "will," which are badly confused in popular thinking. Good and bad are ethical concepts, and science does not render judgment in terms of them. Since a "strong will" is commonly regarded as good and a "weak will" as bad, these forms of choice must be examined by ethics rather than by scientific psychology. It will not be out of place briefly to distinguish them here, however. In general, a strong-willed act is one that considers remote consequences rather than immediate desires. The student who decides to study his lesson is motivated by future needs rather than by those of the moment. The motivation may not be too remote, of course. The desire to do well in class on the next day may be the motive, as well as the higher desire to train himself for a profession. The student who goes to the motion picture responds to an immediate motive, ignoring the more remote results. Another ethical criterion is social utility. The person who chooses to do something that will benefit society in general is deemed to have a more worthy "will" than the one who seeks only his own satisfaction. It is quite evident from the examination of many life situations that the remote and social ends are thought more worthy than immediate or individual ends. Hence, to do the former is ascribed to "strong" will, while the latter are judged to be "weak."

Ethical judgments are based on social traditions and are often modified by time. If an unsuccessful inventor toils at his problem to the neglect of earning a decent living for his wife and children, he is likely to be stigmatized as stubborn or selfish. If his invention suddenly becomes a great success, however, his earlier critics may now praise the "will power" with which he held to his task in spite of adversity. Psychology is not interested in placing a social judgment on an act, but is concerned with the antecedents of the act itself, whether it be good or bad.

Popular opinion often holds, quite incorrectly, that the person displaying will does the thing that he does not want to do, and relinquishes that which he desires. Thus the student

is supposed to persevere at his unpleasant work in spite of a desire for entertainment. This popular view is absurd, for the very fact that the student prepares his lesson demonstrates that he wants to do so more than he wants to go to the motion picture. The only psychological criterion of the stronger motive is the choice that is made. This is a principle used in studying the strengths of the simpler motives among lower animals. A rat may be given the choice of alternative pathways leading to water, food, or its nest. If it chooses the path to the food, the hunger drive is shown to be dominant over the others under the circumstances existing at the time. Similarly, in the case of human choices, the act that is selected indicates which motive is strongest. Fortunately, most human beings are intensely motivated toward ends that have at least some social value.

Factors Influencing Choice. A number of factors can be discovered that determine what alternative an individual will choose when he encounters a conflict of motives. The most important factor undoubtedly is *past experience or habit formation.* The strength of a person's motives is determined principally by the learning processes through which he acquired them. The social motives described in a preceding section are not all of equal intensity in various individuals. One person, through his experiences, may have a strong drive to mastery that stimulates him to try hard whenever he encounters an obstacle. Another may acquire a more easy-going manner, being content to ignore a difficulty and feeling little urge to act persistently toward it. These differences are not innate, but are due to variations in the circumstances affecting learning. Another significant determiner of willful action is that persons may learn various ways of satisfying the same motives. A youngster from a home in which academic achievement is much emphasized will have different motivation toward his studies than one from a home in which scholarship is rarely mentioned. In these cases scholarly attainment

has been conditioned to different amounts of social approval motivation.

The individual's *intelligence* and his *ability to reason and imagine* are factors that determine his choices. A person of low intelligence typically looks for present satisfactions, for he cannot understand the future well enough to plan for remote ends. The feeble-minded individual wishes for candy, or clothes, or entertainment, with the same intensity that the man of superior intellect wishes for professional attainment or business success. The difference is chiefly in the ability to foresee the consequences of a course of action, and to imagine future rewards so vividly that they can serve as present motives. Among persons of the same intellectual level, of course, a similar difference may be caused by training or habit. Over a long period of years, one can acquire more or less of the tendency to evaluate the future as well as the present.

Special ability or *talent* is also significant in the direction of motivation. Biographical evidence seems to indicate that persons who are especially gifted in music, art, science, or literature also usually possess an extraordinary motivation to express themselves in their fields. Great ability may act directly as an incentive, or it may influence decisions because the field of the ability offers the most available road to the satisfaction of more general social motives, such as mastery and approval.

In summary, "will power" is the expression of a dominant motivation over lesser motives. Persons who make good choices do so because of their talents and their intelligence, but above all because they have formed habits of preferring social motives to unsocial ones, and of regarding remote ends as well as immediate gains.

Persons Who Do Not Make Good Choices. The psychological concept of will is clarified by examining the histories of individuals who seem lacking in this trait. Lazy and inert persons will exert little effort, are aroused by nothing, and feel content with their very meager rewards. A few such people

really have too little energy because of physiological defects such as chronic infections, faulty metabolism, or glandular deficiencies. Many, however, are purely psychological cases.

One common cause of lack of volition is continued failure of effort. An individual who tries various tasks without success is likely to give up trying altogether. This is an unfortunate consequence of failure in school in many instances. If, because of dullness or lack of preparation, a student's first attempts in a subject are met with frustration he may become conditioned against effort. The very sight of the subject now arouses fear or frustration, and he naturally turns to more satisfying pursuits which may not be of a constructive nature. Failure to find employment, or lack of success in several positions, may condition a young man against work so that he makes no effort to obtain or keep a job. Popular opinion considers such persons to have "poor character," but they are merely displaying the common tendency of all organisms to avoid distressing situations.

Another cause of poor will power is found in persons for whom circumstances have always been made too easy. If parents satisfy every need of a child without any effort on his part, he learns to expect that others will solve all difficulties for him. This habit is sometimes broken in adolescence or early adulthood when the individual must fend for himself, but often it may continue throughout life.

Fallacies About "Will Power." Because the ability to make good choices among motives is so highly esteemed, many procedures have been suggested for its development. Most of the commonly believed aids to "will power" are fallacies, however, for they will not really cultivate this desirable trait.

One of the most prevalent fallacies is the belief that the performance of difficult tasks cultivates volitional ability. On this hypothesis children were often given extremely difficult school assignments to "cultivate their wills." Such a procedure is utterly useless unless overcoming the difficulty leads to some genuinely desired remote goal. Mere drudgery for its own

sake has no value. Only when the labor has an ultimate reward, visible at the time that the work is performed, does any real training occur.

Closely allied is the belief that unpleasantness or hardship develops "the will." Here again the superficial form has been mistaken for the substance. The hardship that the pioneers endured was evidence of their will because it led to a desirable goal. Merely to experience discomfort, as in the case of the Hindu who stands on spikes or the medieval ascetic who wore a hair shirt, does not necessarily lead to a greater ability to make good discriminations among the motives that conflict in social situations.

Some Nonvoluntary Forms of Behavior

The account of the various forms of voluntary action also involves an explanation of certain acts that are conspicuously nonvoluntary, being performed with a minimum of self-initiation, motivation, or discrimination. Such occurrences include the everyday events of *suggestion* and *empathic action*, and the less common phenomenon of *hypnosis*.

Suggestion. A response that is made to an outside stimulus without deliberation, choice, or thought is ascribed to *suggestion*. This term is especially used to designate *social* stimuli of the type that lead to nonvoluntary action, rather than reflexes and similar automatic acts. A common example of suggestion is the "contagious yawn." If one person in a group yawns, another is likely to do so, and then still another, until the entire group is infected by the reaction. This response is nondeliberate and, in fact, rather difficult to prevent by voluntary action. Another example of suggestion has already been noted earlier in the chapter. If you tell a person to think of falling forward he really will lean forward a little, although he does not realize that he is doing so.

More complex examples of suggestion occur in perceiving and remembering. An individual can be placed at an elaborate-looking apparatus with his hand over an opening and in-

structed to tell when he feels warmth. Several switches are thrown, and most persons will soon report a sensation of slight warmth. But there is really no warmth! The elaborate instructions have been a *suggestion* that leads to an imagined perception of warmth in the absence of the real stimulus. The *words* have been a sufficient stimulus, accepted uncritically. Leading questions often elicit responses by suggestion. In one experiment, a subject who has looked at a certain picture is asked, "Is the man holding the dog by a leash or by the scruff of the neck?" Most persons will answer one or the other, but in the actual picture the man is not holding the dog at all!

Suggestion is often used in advertising or other propaganda. A picture of an inexpensive car standing in front of a fine mansion or an exclusive club suggests the social prestige of owning that car more effectively than many words. One of the common practices of propaganda is to call one's enemies by bad names. These suggest evil qualities and mold the attitudes of uncritical persons far more than does properly documented proof.

No mystery need be attached to suggestion, for it is a simple stimulus-response activity. A suggested response is a direct reaction to an external stimulus without the presence of the internal or self-directive intermediate stimulus that is present in voluntary activity. In *voluntary action*, a command, invitation, or other social stimulus arouses an intermediate response of inner speech or thought, which in turn arouses the act, as was described on page 186. In *suggestion*, the external stimulus elicits the act directly. Evidence shows that suggestibility is a habit phenomenon. Repeated suggestion makes an individual more suggestible, showing the effect of practice. Very young children are not suggestible, but become so by the age of six or seven years when habits of responding to social stimuli have been learned. Older children and adults become progressively less suggestible as the counteracting form of self-directed or "ideomotor" behavior develops more fully. Tests

show that adults of lower intelligence are more suggestible than those of higher intelligence, which is very understandable. Experiments also show that women are more suggestible than men on the average, a fact that is possibly related to the more submissive rôle played by women in conventional society.

Empathic Action. A special case of suggestion is empathic action or *empathy*. Empathy literally means "feeling into"—one person "feels himself into" the action or attitude of another. Watch the stands at a football game. As the team rushes the line the spectators also lean forward and push with it. At a track meet, persons viewing a high jump or pole vault will often lift one foot from the ground and strain with the athlete. Another case of empathy may be seen at an accident, when the faces of the onlookers express the pain that they sense from the individuals who are injured. These empathic actions, postures, or expressions are not deliberate mimicry, and the persons displaying them are usually unaware of what they are doing. As nonvoluntary acts, therefore, they are explained in the same manner as suggestion.

Hypnosis. Hypnosis is an extreme form of suggestibility that can be induced under special circumstances. The method of inducing it consists in getting the subject to accept some easy suggestions, then leading on gradually until he acts upon more unusual suggestions that he would have rejected without the preparatory steps. In setting up a state of hypnosis, the experimenter places the subject in a comfortable position, and often has him look at a bright object near to and slightly above the eyes; this induces a real eye-muscle fatigue. Suggestions are then given: "You are feeling drowsy, you can hardly hold your eyes open, you are falling asleep, etc." These verbal suggestions are in line with the actual situation in which the subject has been placed, and are usually accepted readily. The subject closes his eyes. As soon as this one suggestion has been acted upon, the experimenter gives further suggestions such as that the subject cannot now open his eyes,

open his hand, or stand up. The acceptance of these suggestions puts the subject in a state of *habit* of accepting further ones, and the experiment can proceed.

A large number of suggestions can be imposed upon a hypnotized subject. When told that his arm is rigid, it becomes so. He can be pricked with a pin without wincing if he is told that it will not be felt, but he will writhe in agony upon being touched with a pencil if the experimenter says that it is a hot iron. The subject will acknowledge that he sees nonexistent objects or persons when the experimenter gives the appropriate suggestions, or will say that he does not see things that are present, if it is so suggested. He will perform irrational acts, such as chasing a nonexistent butterfly, when told to do so.

None of these phenomena of rigidity, of seeing visions or of doing foolish acts, is essential to the hypnosis itself. They occur only when they are suggested. Research has shown that very similar responses can be evoked by ordinary suggestion to an unhypnotized subject, but that hypnosis makes them easier to elicit and increases the certainty and intensity of the result. It is probable, therefore, that hypnosis may be regarded as an exaggeration of suggestion.

There are many popular misconceptions about hypnosis. The hypnotist has no extraordinary "personal power"; he merely knows how to proceed. Most persons can learn how to induce hypnosis, although a commanding personality, a good voice, and a reputation for success in the task are valuable assets. No hypnotist can hypnotize a new subject in a moment or two by looking in his eye, by pressing on his head, or by making passes with his hands. It takes time, patience, and much talking to hypnotize a person for the first time. On subsequent occasions, because of suggestions remaining from previous experiences, the state can be induced more rapidly. Hypnotizers who seem to violate this statement, as in exhibitions on the stage, either use practiced subjects or else are frauds.

In the hypnotic state the subject will not perform acts that are too remote from his concepts of decency. He will not attack persons or disrobe in public, for example. If these are suggested, he resists and often comes out of the hypnosis. He is therefore "in the power of the hypnotist" only in a very limited degree. It is also false to believe that the subject shows much greater strength or much greater sensory sensitivity when in hypnosis. Experiments show that all hypnotic phenomena that seem superhuman, such as rigidity, can be reproduced by the subject voluntarily if he will try hard enough.

The Significance of Voluntary and Nonvoluntary Action. Suggestion, empathy, and even hypnosis are not hard to explain psychologically. They are $S \longrightarrow R$ activities based on habit. All through childhood the habits of doing as one is told and of believing what others assert are persistently cultivated. These habits are undoubtedly useful and necessary for social life. Experiments in suggestion and hypnosis merely take advantage of these submissive and thoughtless habits to achieve striking results. Suggestion plays a large part in everyday behavior, but the influence of this factor is usually unnoticed because of its very nature. The experiments in suggestion are not revelations of strange phenomena, but are only exaggerations of a common mode of behavior.

Of a higher order in human affairs, and requiring more detailed explanation, are the voluntary phenomena of self-direction, discrimination, and choice. These actions are more complex than the ones involved in suggestion. Voluntary acts necessitate intermediate processes between the first stimulus and the final response. The intermediate steps are themselves $S \longrightarrow R$ patterns involving language, ideas, and other tools of thought. Only by the intervention of these symbolic processes is the greatest effectiveness of human behavior achieved.

Chapter VIII

THE GENERAL NATURE OF EXPERIENCE

Experience

Man is a conscious organism as well as a reacting one. Every human being is aware of much that is going on, both in the external world and within his own body. Experience, or consciousness, is therefore apprehended very directly by all people, and is one of the simple and evident facts of living. Intelligent persons through all the ages have given much thought to the interesting and striking problem of the nature of experience, consciousness, and ideas; but in spite of its universality, experience has proved a difficult phenomenon to investigate scientifically. The difficulty is due in part to the private and personal nature of consciousness, for a person's awareness at a particular moment can be experienced by that person alone. It is a unique event that cannot be examined by an outside observer or repeated exactly at some later time. This is in contrast to overt behavior which can be observed and verified by as many experimenters as may be present. Experience is thus less susceptible to certain useful types of scientific inquiry than is behavior. A still more serious impediment to the study of conscious activity is the mass of superstition and misconception with which it is encumbered. To investigate conscious experience psychologically it is necessary to lay aside many prejudices and to undertake the problem anew with a fresh and simple outlook.

Characteristics of Experience. Two elementary characteristics of conscious experience can be established by every person through a brief examination of his own awareness. First,

every experience is an *awareness of something*, never an isolated condition that can exist by and for itself. Most frequently, an individual is aware of the objects and events in his environment. He sees the book before him, hears the clock tick, or senses the heat from the fireplace. Consciousness of his own body is also always present. He feels an itching of his ear, fatigue of his legs, and the complex pattern of skin, muscle, and internal sensations that comprise the most elementary form of self-consciousness. A person may also be aware of words, relationships, remembered events that were experienced in the past, or imagined ones that may happen in the future. In each instance, however, awareness has some subject matter beyond itself of which it is the awareness. It is a part of the individual's entire adjustment to his world.

A second essential characteristic is that awareness is *always an activity*, a dynamic occurrence, a happening. It is never a static thing or entity. An experience occurs only as it is being experienced. This is a simple truth that every person can verify by observing himself, but it is often thoughtlessly denied by common forms of speech and popular belief. Thus it is commonly said that a person "has" or "possesses" an idea, or that he "has" a pain. These statements are incorrect, for the experiences are not existing things, but are moving and transient occurrences. Similar events occur in the physical world. The wind is not a thing but a happening. The air molecules do not have the properties of wind; only their acting in a certain way produces the characteristic effect. If a dog jumps into a chair, where is the jump after he has jumped? It no longer exists, for it is an activity and can have existence only when it is being done. Just so, an idea exists only while it is being thought. The study of human experience is a study of adjustive activity, not an examination of passive states of being.

If consciousness is so fleeting, how can it be tied down for scientific study? By the same means as that by which the physicist studies any change or motion. As Titchener wrote: "In strictness, we can never observe the same consciousness

twice over; the stream of mind flows on, never to return. Practically, we can observe a particular consciousness as often as we wish, since mental processes group themselves in the same way, show the same pattern of arrangement, whenever the organism is placed in the same circumstances. Yesterday's high tide will never recur, and yesterday's consciousness will never recur, but we have a science of psychology, as we have a science of oceanography."[1]

Experience and Behavior. Most situations arouse both experience and behavior, for both doing something and being aware of something are required for effective adjustments. In many instances, however, behavior may occur without any accompanying awareness. For example, a person's blood pressure may rise when he is confronted by an embarrassing predicament, but he will not know about this response unless it is measured by instruments. Many important reactions, especially organic adjustments and emotional changes, are similarly "unconscious" in that they are unaccompanied by awareness. At the opposite extreme, some responses may consist only of consciousness, without any corresponding muscular reaction. These are less common, but it is possible to present a simple stimulus, such as a red disk, under conditions so controlled that no movement occurs, yet the individual is aware of the color. In sequence of time, awareness may precede, accompany, or follow the reaction that is a part of the same adjustment. Popular belief holds, often quite wrongly, that first a person is aware of a situation and then he acts upon it. This is not always true. Quite frequently awareness and muscular behavior start together, and in some cases awareness may not occur until the reaction is well under way. Especially in very well-learned habitual responses, we tend to act first and think afterward.

In practical affairs, experience or consciousness has a profound effect upon the efficiency of muscular behavior. Com-

[1] Edward Bradford Titchener, *A Textbook of Psychology,* 1905, p. 19. By permission of The Macmillan Company, publishers.

pare, for example, the performance of two men who are trying to repair a lock. The one who does not understand how the lock operates will fumble more or less aimlessly by motor trial and error alone. The other, who understands the principles upon which locks are constructed, can do better even though he has not attacked this particular lock before. He sees the parts of it not as a jumble of pieces, but in their functional relationships with one another. Therefore he can think or imagine the working of the lock in a clear and definite way. These conscious processes add greatly to the efficiency of his work, for he displays "insight" or understanding that serves as a guide to motor activity. It is clear that awareness is not a high and mysterious process, but is inseparable from the adaptive behavior of everyday life.

An ancient philosophical problem dealt with the relationship between conscious states and bodily processes from a somewhat different point of view. The two chief types of theories were the dualistic and the monistic. The older *dualistic* theories held that mind (consciousness) and body (physiological processes) were entirely separate entities, different in kind and quite incomparable. It was admitted, however, that each could influence the other. Modern thinkers favor the *monistic* theories, that an act of consciousness and its concurrent neural process are one and the same event, but observed in two different ways. It is possible to know that rain is falling either by seeing it or by feeling it. Similarly, a sound may be known directly by hearing it (awareness), or indirectly by the use of delicate electrical devices which pick up the neural action currents from the inner ear. Experience and neural process, or mind and brain, are therefore two aspects of the same event, rather than separate entities.

Sensation and Perception. Psychology deals with two basic categories of conscious experience, sensation and perception. Theoretically, sensation is the simpler of the two; it results directly from the adequate stimulation of any sense organ. There are as many kinds of sensation as there are kinds of

receptors, and these sensations furnish the ultimate basis of all conscious experiences. Sensations are the immediate responses to the physical events that act upon receptors. Therefore, in terms of sensation alone, we see light and hear sound. Sensations are "pure" experiences in that they do not have organization, meaning, or association.

Perception is conscious experience that has some degree of organization and meaning. While by visual sensation we see only light, by perception we see objects. Except under special conditions, all the direct experiences of an adult human being are perceptions. Pure sensations are difficult to isolate, because all that is seen, heard, or otherwise received is modified greatly by previously formed habits and by the present background and context. Looking upward out of doors on a cloudless day should give a pure sensation, for the eye receives an objectless blue, but the habit of perceiving things is so strong that we invent an object where there is none and say that we see "the sky." Only the trained artist or the practiced psychological observer approaches seeing a pure sensation, and then only imperfectly.

The relationship between sensation and perception may be deduced from the definitions of these two concepts. Physiologically, a perception is made up of a pattern of sensations. But psychologically, the reverse is true. A perception of an object or thing is the real and basic process of experience. Sensations are derived units into which a perception may be broken down by careful observation and analysis.

The Dimensions of Consciousness

All events in the physical world, no matter how complex, can be described ultimately in terms of certain simple variables that form the fundamental dimensions of physics. These basic dimensions are space, mass, and time, which may be measured by the metric units of the centimeter, the gram, and the second, and hence are known as the c.g.s. system. These three variables were thought to be entirely independent at one time, but

modern physics has shown that certain relationships exist between them.

Conscious experience also has its dimensions, which are not evident in the crude perception of a total situation, but may be discovered by analysis. The dimensions of consciousness are more numerous than those of physics, and somewhat more complex. First, experiences differ in *kind*; they are visual, auditory, or of some other type. The elements into which conscious experiences of any kind can be analyzed are *quality*, *intensity, duration, extent,* and *pleasantness* or *unpleasantness.*

Kind. The most fundamental distinction between sensations is in kind, for every experience belongs to some sensory realm or modality. A sensation is an experience of vision, or of hearing, or of taste, or of pain, or of some other sensory type. The differentiation of kinds of sensation is due to the specific functions of the sense organs, their nerves, and the parts of the cerebral cortex with which they are connected. The visual mechanism sees; it cannot hear, and most of the other receptors are similarly specific. Of course, one physical stimulus may act upon more than one sense organ. An electric shock applied to the eye may cause both a sensation of pain and an apparent flash of light. More commonly, one physical object may set up stimuli for several kinds of sensation, as when one both sees and hears the approach of a locomotive. In fact, the development of object perceptions requires the association of various sensations from a single object.

Quality. Each kind of experience may exist in a number of different qualities. A visual sensation may be of red, green, blue, or some other hue or mixture of hues. A heard pitch may be high or low, a taste sweet or bitter, a smell fruity or putrid. These various qualities of experience will be described in detail in the following three chapters. In most instances the qualities of a sensation can be referred to quantitative variations in the physical stimuli that evoke them. The visual qualities of hue are responses to various wavelengths or frequencies of light waves which can be defined in terms of the space or

time dimensions of physics. The qualities of taste and smell are less easy to describe in numerical terms, but may be ascribed to the chemical structures of the stimulating substances. Certain skin sensations of pain, pressure, warmth, and cold offer some uncertainty as to whether the differences are of kind or of quality, as will be discussed in Chapter XI.

Intensity. An experience of any kind or quality is always present in some quantity or amount. Tones may be loud or soft, lights bright or dim, lifted weights heavy or light, and tastes and odors strong or faint. Intensity is thus the dimension that indicates "how much" of a sensation quality is present. The physical basis of intensity is chiefly the amount of energy or force with which the stimulus acts effectively upon the sense organ, a sufficient increase of stimulus energy producing an increase in the intensity of sensation. Physical energy is not the sole determiner of sensation intensity, however, for the state of preparation or adaptation of the organism is also significant. The neural basis of intensity has been the subject of much investigation. According to the "all-or-none" law, a single nerve fiber responds with only one degree of excitation if it acts at all. Therefore intensity is believed to be a function of the frequency or rate of impulse discharge in the fiber, and of the number of fibers conducting, which in turn depends on the strength of the stimulus. As the stimulus increases in energy, the frequency and number of impulses increase, and the greater is the intensity of sensation.

Duration. Every experience has duration; once begun it continues for a certain period of time. Duration is therefore the temporal aspect of consciousness, the awareness of the persistence or continuation of a sensation quality. When an estimate is made of the duration of a sensation it becomes a time interval. Psychological time is not identical with physical time, however. First, the ability to judge the duration of time varies with the length of the interval. Very short times are sensed as longer, and long times are usually perceived as shorter than they are physically. The total adjustment of the

individual also enters into his perception of time. An interval filled with stimulation or activity seems much shorter than an equal interval of "empty" time, and a short wait while one is prepared for something to happen may seem interminable.

Extent. Extent is the spatial property of experience, the dimension that indicates its size, shape, or position. This property occurs most clearly in the realm of vision, where every object experienced is located in a certain place, has height, length, and depth, and is circular, square, or of some other shape. In the field of hearing, tones are only fairly well located as to distance and direction. Tones often give the impression of having size and shape, being described as "massive" or "sharp," but it is doubtful whether these are fundamental dimensions of audition. The skin senses of pain, pressure, warmth, and cold have well-defined spatial properties and are located on the surface of the body with reasonable precision. As a result of learning, an adult can tell where he is touched, the extent of the contact, and even the contour of the touching object. For tastes and odors the perception of extent is not so precise. Taste has no position at all, and a smell can be located only by an exploration which uses the intensity of an odor as a cue to its position.

Pleasantness and Unpleasantness. Conscious experience possesses, in addition to the more elementary sensory properties that have been described, certain "feeling" aspects; that is, it is pleasant or unpleasant in some degree. These feelings of pleasantness and unpleasantness are closely related to an individual's *likes* or *dislikes*, and as such represent a psychological property that coexists with every sensory stimulation. This property has been given the technical name of *hedonic tone.* Hedonic tone varies in a single continuous scale from unpleasantness through indifference to pleasantness. It is determined by many factors, so that what is pleasant at one time may become unpleasant at another, or what is slightly pleasant or unpleasant may become indifferent when the conditions are

changed. The most obvious conditions influencing hedonic tone are the intensity and the quality of the sensation.

Common daily experiences offer many examples of the influence of the strength of a stimulus on hedonic tone. A soft sound is pleasant, but the same sound at a much stronger intensity may become unpleasant to the point of pain. A gentle touch is pleasant, an intense pressure painful. A pleasant sweet taste becomes unpleasant when too sweet. The smell of orange blossoms is delightful, but the odor of an orange grove in blossom is almost intolerable. The different qualitative experiences of color, sound, taste, touch, and smell also differ somewhat in pleasantness-unpleasantness. To many people green and blue are pleasant hues, while yellow is more often reported as unpleasant. In the realm of sound it is found that high-pitched tones tend to assume unpleasant qualities and that the highest pitches become quite agonizing. In the tactual field a smooth contact is pleasant, a rough one is more likely to be unpleasant. Fruity, flowery, spicy, and resinous odors are pleasant; putrid and burned sensations of smell are unpleasant. Again, an otherwise agreeable experience may become disagreeable if it is too short or too long in temporal duration.

Another factor that modifies hedonic tone is *contrast*. An experience that is pleasant when it occurs by itself may lose its degree of pleasantness, or may even become unpleasant, when it is preceded or followed by a like experience that is more pleasant. The same holds for the *context* of the experience. A disagreeable discord may be quite acceptable and even pleasant when it is one chord in a harmonic succession. *Habituation* is another important influence in hedonic tone. That which is novel and unexpected, and departs from the usual and customary, is often unwelcome and unpleasant, but in time it may pass over into pleasantness. In the arts particularly we tend to reject the new until it has become the old. *Individual differences* in sensitivity and in past experience also affect hedonic tone, so that what is pleasant to one person may be

unpleasant to another. The trained musician or painter shudders at what the untrained layman gladly accepts as music or painting; a melody played off pitch is agonizing to a very sensitive ear, but is neutrally received by a person whose pitch acuity is not fine enough to sense the discrepancy.

The Measurement of Experience

Psychophysics. Conscious experience may seem to the layman to be made of very delicate stuff, and a proposal to measure it exactly may appear unduly audacious. On the contrary, some of the earliest experiments in psychology dealt with just this problem, and some of the most precise researches have been conducted in this field. The principal experimental studies of conscious experiences have investigated the correlations between stimuli and their resulting sensations. This is the field of *psychophysics*, or the exact measurement of the relationship between the variations in conscious sensations ("psycho-") and the variations in the objective stimuli ("physics") that will elicit them. Experiments in psychophysics combine precise instrumental control of the stimuli presented, with the introspections or inner self-observations of the individual who reports his sensations. A large number of complicated experimental and mathematical techniques are used in psychophysics. These methods are beyond the scope of this book, but the chief concepts, principles, and results will be summarized.

Thresholds. A certain minimum intensity of stimulus energy is necessary to provoke a response of conscious sensation. For example, a sound must attain a certain intensity at the ear in order to be heard at all. The minimum energy adequate to evoke a conscious sensation is the *threshold* (or *limen*) of that sensation. Many energies reach sense organs so faintly that the individual is not aware of their presence. Such physical events are below the threshold, or *subliminal.* Once above the threshold, the intensity of sensation increases with increased energy of the stimulus, but not proportionately, as

will be seen. There is also an upper limit of stimulus intensity beyond which any increase will fail to add to the magnitude of the sensation. In some sense modalities, a stimulus may even be so strong that it results in a different kind of sensation. For example, a sound may be so powerful that it causes an experience of pain instead of one of hearing.

The threshold of a sensation is usually obtained by adjusting the intensity of the stimulus until the observer can just perceive it. To determine an auditory threshold, for example, the

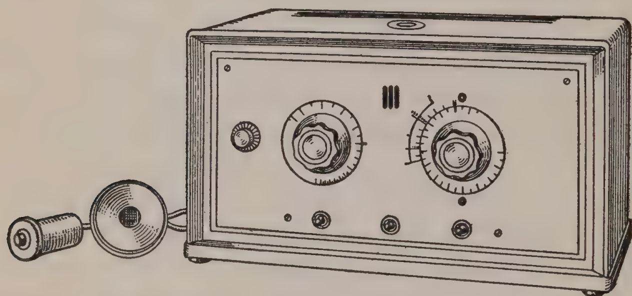


FIG. 49. An Audiometer for Determining Thresholds of Hearing.

The Western Electric Type 6A Audiometer is used for practical tests for the hard-of-hearing. The large dial at the left varies the pitch of the sound produced, and the dial at the right varies its loudness. The person being tested holds the telephone receiver to his ear, and signals with the push button when he hears the sound. The instrument is calibrated against normal ears. To determine the threshold in physical units (such as dynes per square centimeter, see Chap. X) further calibration is required. (Courtesy of Western Electric Co.)

observer is tested in a quiet room. A sound of medium intensity is made and is decreased by steps until the observer no longer hears it (Fig. 49). Determinations of the threshold intensities for various qualities of the same kind of sensation are also made. In visual sensation, yellow light has a much lower threshold than red or blue light. That is, an observer can see a very faint yellow light, but red or blue must have several times as much physical intensity in order to be perceived.

Experiments can determine the least amount of *change* in the energy of the stimulus that will cause a perceptible change in the sensation. If an observer is looking at a lighted area of

given intensity, how much additional light is required to make it just noticeably brighter? How much additional mass is needed to make a lifted weight feel just noticeably heavier?

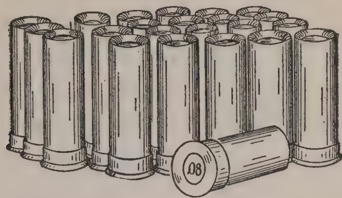


FIG. 50. Weights for Determining Kinesthetic Threshold.
The set of weights consists of a standard, and a series of comparison weights that are successively heavier than the standard by half-gram steps. The blindfolded subject lifts the standard and a comparison weight in rapid succession and reports which one seems heavier. By the use of a series of comparison weights the least perceptible difference, or difference threshold, can be determined. (Courtesy of C. H. Stoelting Co.)

The minimum increment of stimulus energy that will produce a "just noticeable difference" is called the *difference threshold* or *difference limen*. Figs. 50 and 51 show some apparatus used

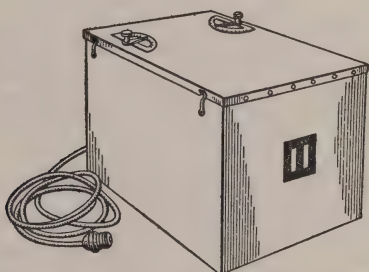


FIG. 51. Apparatus for Determining Brightness Discrimination.
The brightness of the two translucent windows in the front of the box can be varied independently by adjusting the angles of reflectors within the box. One window is set at maximum brightness, and the intensity of the light on the other window is decreased until the difference is just noticeable. (Courtesy of C. H. Stoelting Co.)

to obtain difference thresholds. To determine a threshold for differences in weights (kinesthetic sensation), the blindfolded observer "hefts" a small standard cylinder weighing, for example, 100 grams, and then one a little lighter or a little

heavier. He reports which cylinder seems heavier. Cylinders of various weights are tried until the minimum difference that he can detect consistently is determined. Usually an observer can detect about a two-gram difference from a standard of 100 grams, that is, he can consistently tell that 102 grams is heavier than 100, but not that 101 is heavier than the standard.

The earliest psychophysical experiments dealt with intensity thresholds, and these studies continue to be important. But thresholds can be determined for qualities, extents, and dura-

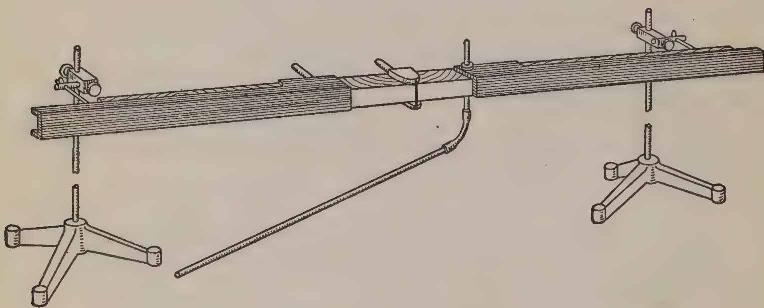


FIG. 52. Galton's Bar.

The experimenter sets the length of the left-hand segment of the exposed white bar. By turning the long rod, the subject adjusts the length of the right-hand segment until it appears to be equal. The actual lengths of the segments can be read from scales on the back of the bar, and the just noticeable difference in length can be determined. (Courtesy of C. H. Stoelting Co.)

tions of sensations as well. The pitch difference threshold is an example of a quality threshold. A tone of standard pitch is sounded, and then one a little higher or lower, the observer giving his judgment. Thresholds of duration are obtained similarly. Three clicks may be sounded to mark off two intervals of time, the observer judging whether the interval between the second and third click is longer or shorter than that between the first and second click. By adjusting the time intervals the difference threshold for time perception can be obtained easily. Fig. 52 illustrates "Galton's bar," a device used for obtaining one kind of spatial threshold. The experimenter sets the length of one segment of the white bar, and

the observer then adjusts an adjacent segment until it appears to be of equal length. The accuracy of the perception of length can thus be determined for various lengths of lines.

The Weber-Fechner Law. The most important law of psychophysics was announced by E. H. Weber in 1834, and amplified by G. T. Fechner in 1860. The Weber-Fechner Law deals with an effect that can be easily observed by everyone; a few ordinary illustrations will clarify the formal statement that follows. If one lighted candle is added to two, a distinct increase in illumination can be perceived. But if one candle is added to sixty already burning, the increase in light may not be noticed. Adding one instrument to an orchestra of five pieces will increase its loudness, but one more piece in a band of one hundred will not cause a noticeable difference. In a laboratory experiment, a blindfolded observer can detect a difference in weight between 100 grams and 102 grams, but he cannot judge correctly a difference between 200 grams and 202 grams. An equal increment in stimulus intensity does not have an equal effect upon sensation, but its influence depends on the magnitude of the stimulus that is increased.

The original statement of Weber's Law declared that the stimulus change (dR) that gives a just noticeable difference of sensation bears a constant ratio to the magnitude of the stimulus (R). As a formula, this may be written:

$$\frac{dR}{R} = \text{a constant.}$$

Thus if the difference between 100 grams and 102 grams is just noticeable, then one would find 200 just perceptibly different from 204, 400 from 408, 600 from 612, and so on. Further experimentation has shown that Weber's Law is true for the intensity variations of all modes of sensation, and for many variations of quality, duration, and extent. It holds precisely, however, only in the middle range of magnitudes. Both in very low and very high magnitudes of sensation, differences are harder to detect than Weber's Law would indi-

cate. The "constant" fraction of Weber's Law is not the same for the various kinds of sensation, but each sense has its characteristic constant, as given in the list below. That Weber's constant for visual brightness is about 1/60 means that an increment of 1/60 in the brightness of any light source yields a just noticeable difference. It must be remembered that these values do not hold for very weak or very strong stimulation, and that different methods of determination may give slightly different constants.

Sense Function	Approximate Weber's Constant
Visual brightness	1/60
Kinesthesis (lifted weights) . . .	1/50
Auditory loudness	1/10
Smell intensity (rubber)	1/10
Cutaneous pressure	1/7
Taste intensity (salt)	1/5

Fechner added to Weber's Law by postulating that all just-noticeable differences of sensation are equal. That is, the

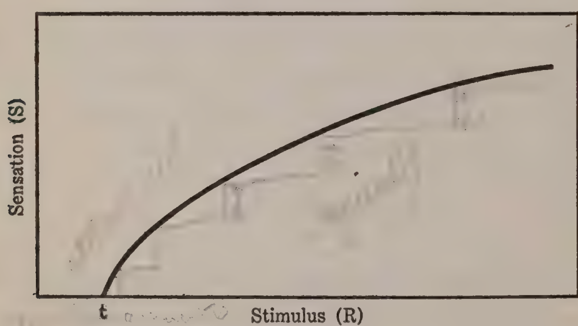


FIG. 53. The Weber-Fechner Law.

The physical intensity of the stimulus is shown along the horizontal base line, and the intensity of the resulting sensation as the vertical distance. The threshold (*t*) is the minimum stimulus energy necessary to cause a just noticeable sensation. The general shape of the curve is logarithmic, and shows that equal increments of stimulus intensity cause successively decreasing increases of sensation.

sensation difference between 100 and 102 grams equals that between 200 and 204 grams, even though the increments of

stimulus mass are, of course, unequal. On this hypothesis, Fechner's Law is written:

$$S = k \log R$$

The intensity of the sensation (S) increases as a constant times the logarithm of the stimulus (R).[2] The relationship between stimulus and sensation indicated by Fechner's Law is shown in Fig. 53. It is a relationship of *diminishing returns*, since larger and larger additions of stimulus energy are required to produce equal increments of conscious sensation.

There are many common observations that illustrate Weber's and Fechner's Laws. We cannot see the stars in the daytime, although they shine then with exactly the same intensity as at night, because the greater light of the sun throws them below the difference threshold of perception. The years seem shorter as one grows older because the comparison unit of the time of one's whole past life has increased. In peaceful years a disaster involving ten deaths receives national notice, but during a period of war thousands of casualties cause little excitement, again because the standard of comparison is of such greater magnitude. The Weber-Fechner function even applies to advertising, which is a psychological problem because it seeks to attract the attention of people. The value of a newspaper advertisement increases not in direct proportion to its size, but more slowly, so that an advertisement ten times as large produces only about three times as much attention. The Weber-Fechner Law is thus not a dry abstraction of the psychological laboratory, but a principle that enlightens many interesting and practical matters of ordinary life.

The Development of Experience

Experience Begins with Wholes. Perceptual experiences occur originally as organized wholes. That is, experience does not begin with a number of separate sensation units which

[2] Fechner's Law is derived from Weber's Law by a simple operation of the integral calculus.

are then bound together into a single situation. Instead, there is some organization in even the simplest and earliest experiences, although it may be incomplete and vague. For example, we see a square as a direct, immediate experience and not as the sum of four lines. A musical melody is heard as a unitary experience, not as a number of separate sounds in succession. The melody, in fact, would disappear if each tone were heard independently as it occurred. When we hear a person speak to us, he is uttering a number of distinct words, but we grasp those words directly as one idea. Of course, the perceptual whole is made up of parts, and consists only of those parts which subsequently become known as the components of the whole. Binet found that a line drawing observed for a brief period is first seen as a whole, the details being noticed only after several successive exposures. Reaction time experiments show that the time required to see a whole word is slightly shorter than that needed to see a single letter in it, indicating that words are read as wholes, as immediate responses, and not by spelling them out. If a series of unrelated words is exposed at one time, each word can be read aloud about twice as fast as a single isolated word, and words that make sentences can be read aloud about four times as fast. When an individual is learning to sing a tune the first attempts at reproduction are correct only in the up and down movements; the accuracy of detail, note for note, is a later acquisition. Persons asked to reproduce drawings shown to them have found the task easier if they fixate upon the design as a whole rather than upon the contours of the figure. All these results indicate that the natural, original response of an adult is to organized wholes.

Whether the first conscious experiences of infants are organized wholes cannot be determined directly, for such young children are unable to report their own conscious processes. Some indirect evidence based on observations of child behavior, however, indicates that perception occurs from birth. A very young child understands spoken phrases as wholes long before he understands analytically the separate words or sounds of

which they are composed. When the child first learns to produce language, he names concrete things first, while words for abstract sensation qualities such as red, round, loud, and the like come somewhat later. His motor behavior develops from general to specific, as was described in Chapter IV, which leads to a reasonable presumption that the same sequence is likely to operate in the growth of awareness.

Learning to Perceive Things. A child's perception of an object differs greatly from that of an adult, and even an adult perceives a familiar thing quite differently than an unfamiliar one. Improvement in the perception of an object is a process of learning, similar in most respects to the formation of a habit. In habit formation, general and diffused behavior becomes more specific when practiced under the right conditions. Also, a vague and undifferentiated experience becomes more definite and clear as an individual comes in contact with it repeatedly.

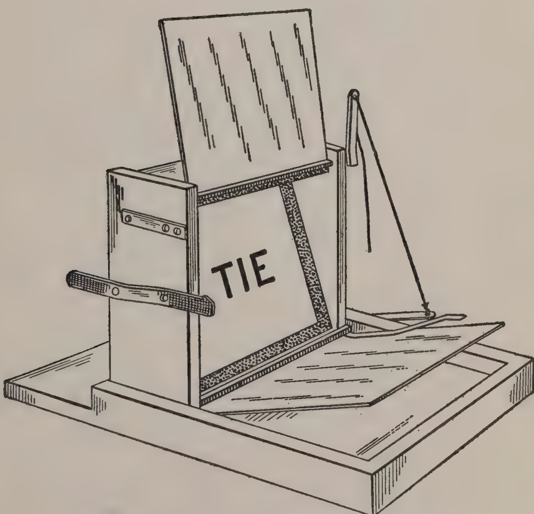


FIG. 54. A Tachistoscope.

A tachistoscope ("speed-viewer") is a device for exposing a visual stimulus for a brief time interval. The simple falling-door model is shown, in which the lower door falls to start the exposure, and the upper door falls immediately afterward to terminate it. The exposure time is approximately 1/10 second. (Courtesy of C. H. Stoelting Co.)

It is usual for a clear perception to develop gradually. A first glance at an unfamiliar object gives only an inadequate perception of it. The clearness of perception increases with subsequent views. There is therefore a certain amount of "trial and error" in perception. The first awareness is not only vague but is likely to be incorrect in many respects. With

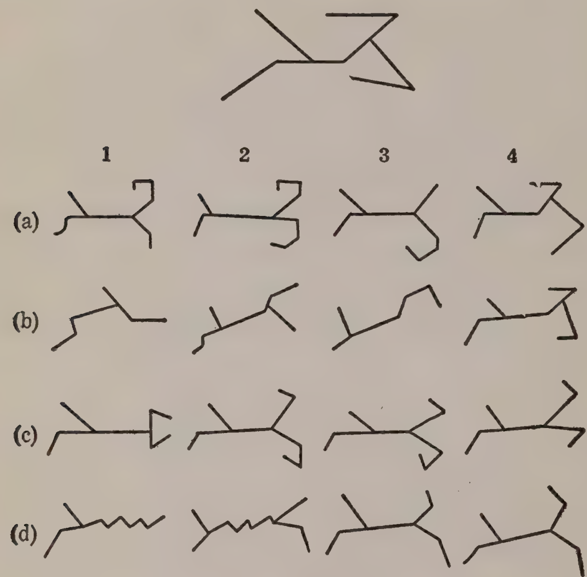


FIG. 55. The Growth of a Perception.

The figure at the top was exposed for 1/10 of a second in a tachistoscope, four successive times. After each exposure the subjects drew their perception of the figure. Columns 1, 2, 3 and 4 show the successive drawings made by four observers *a, b, c* and *d*. Note that a general impression of the total form is obtained at first, while subsequent exposures result in an increase in the number of details perceived correctly.

repetition, the errors tend to decrease and the correctness and scope of the experience improve. This process can be shown by a simple experiment. A card on which a simple figure is drawn is placed in a *tachistoscope* (Fig. 54), an apparatus that exposes visual material for a brief and definite interval of time. The figure is exposed and the observer is required to draw it. Then the figure is shown again and again, with a reproduction after each view. Fig. 55 shows the result of such

an experiment. Two conclusions may be drawn from an examination of this figure. First, it is evident that a vague whole impression is obtained from the initial view. Although incorrect, the perception is of the whole figure, not of some of its parts or details. Second, the operation of trial and error is evident. The correctness of the figure increases gradually, each reproduction showing some improvement over its predecessor.

The growth of a perception in everyday life is a similar process. As a child gets acquainted with a house, a dog, or a toy, or as an adult has successive experiences with a complicated machine, the perception of each improves by trial and error. Of course, erroneous perceptions can persist for a long time in spite of opportunities for improvement. In motor skills such as handwriting, gains in efficiency do not come about automatically with practice but occur only if the conditions are appropriate for learning. Just so, a person may see a building or a machine many times and still have a very inadequate perception of it because he has not learned with each experience.

Factors in the Growth of Perception. Two important processes that operate in the growth of a perception may be distinguished. First, the awareness of a perceived object assumes *increased clarity of detail.* As an instance we may examine the development of a perception of a person, the process by which one comes to know him as an individual. The vague and general perception of him becomes filled in with detail as the acquaintance progresses. We note the exact cast of his features, the shape of his hands, and the texture of his hair. More significantly we note details of his typical behavior. His speech, his mannerisms, his preferences, and his characteristic responses to a variety of situations are learned, and these observations enrich the perception of him as a person. The same process can be recognized in gaining a knowledge of a machine. The driving mechanism of a locomotive is perceived at first without clarity and definiteness. Later the details become clarified in terms of cylinders, valves, pistons,

connecting rods, and other parts. So in any perception, the vague outline becomes filled out with detail, giving it definiteness and uniqueness.

The second chief process in the growth of a perception is the *increase in scope* of the awareness aroused by an object. In a sense this is the reverse of the first process which analyzes more detail. In becoming acquainted with a person, we relate his existence to the larger wholes of which he is a part. He has the properties of a human being, and all knowledge about mankind in general is applied to him. Every new grasp of knowledge about people in general, such as may come from the studies of anatomy or physiology or psychology, may serve to broaden the scope of our knowledge of a particular man. We also may note that he comes from Massachusetts, that he is a physician, a Presbyterian, and a graduate of Yale. Thereupon all our past knowledge of Yankees, doctors, Presbyterians, and Yale men become transferred in some degree to the perception of this individual. While errors may occur from an assumption that all members of such groups have characteristics in common, this broadening of perception is a useful supplement to the increase in detailed and particular knowledge. Increase in scope also applies to the growth of the perception of a machine. Everything that is learned about the history, development, and uses of locomotives, or about the applications of cylinders, valves, and pistons in other mechanisms, broadens the state of awareness that this particular machine may arouse.

Practical application may be made of the analysis of an act of perception in terms of increased clarity of detail and increased breadth or scope. In order to perceive efficiently, these processes may be used deliberately. To know a person well, carefully observe and enumerate his detailed characteristics, and also relate him to the regional, occupational, or political groups of which he is a member. Such people as eminently successful politicians who know thousands of people are able to do this, not so much because of a special "gift"

as by close attention to details and by habits of appropriate generalization. To gain a clear perception of a machine, examine and enumerate its parts, relationships, and functions. Also compare it with other machines so as to note similarities and differences and thus bring to bear upon the new object all the applicable knowledge that has been learned in similar situations in the past. There is some evidence to indicate that excellent habits of perception that are both detailed and broad distinguish eminent leaders, scientists, artists, and business men.

Meaning and Language

Meaning. When an individual perceives a situation or object it may be said that he has *knowledge* of it, or that it has *meaning* for him. Meaning is a psychological event, not inherent in the situation itself, but emerging from the relationship between the individual and the situation. Broadly defined, *the meaning of a situation is the response that it evokes*. Meanings, of course, can be comprehensive or narrow, correct or incorrect. To a child, fire has some meaning when he avoids it consistently; to him it means only something that can hurt. An adult has a broader meaning of fire, for he avoids it at times, uses it when it is needed, and controls or extinguishes its spread when this is appropriate. To a scientist fire has a much broader meaning when he sees it as the result of certain chemical reactions or as the possessor of certain physical properties. All these persons—the child, the adult, and the scientist—know the meaning of fire, for they all respond to it in an adaptive manner, but their meanings are not the same. The broader meaning permits a much wider and more useful hierarchy of adjustive responses, determined by the total situation in which the fire is encountered.

To an individual, meaning usually occurs as a process of experience, that is, as an act of perception. Knowing a situation consists of perceiving it clearly and broadly. This inner experience will not serve to express the meaning to other

persons, however, since no one can sense the perceptions and thoughts of another individual. Meanings are expressed to others in two principal ways, by *behavior* and by *language*. The most reliable information concerning the meaning that a situation has for an individual can be obtained by observing his responses to it. If he can adjust successfully to the situation it has meaning for him, and the greater the precision and scope of the adjustments, the greater is the meaning.

Language is the commonest and most explicit method of expressing meaning, and as such deserves special consideration in the study of perception. Language is not entirely different from other forms of overt response, since it conforms to the principles of habit formation. The production of oral language is a muscular reaction involving the chest, larynx, and mouth, and is learned in the same way as other motor acts are acquired. In use, however, language is a remarkably flexible system of signs that can stand for various meanings. The meaning of a word is the same as the meaning of the object, act, or relationship that it signifies. Since the meaning of a thing is the individual's response to it, so the meaning of a word is also such a response. As one of the ancients adroitly expressed it, "A word is the shadow of an act." Whether a word has meaning can be determined only by observing whether the word will arouse an individual to some activity.

There is no inherent connection, of course, between a word and its meaning. A word is an arbitrary sign, developed through a long sequence of cultural history, that by common agreement designates a certain meaning. Cultural groups acquire new words, and often new meanings for old words, by learning processes that are usually gradual but sometimes quite sudden. Each individual learns in childhood the language of his group, but he would adopt a different set of arbitrary signs just as readily if he were reared in a different language area.

Language is a most convenient and efficient tool for indicating meanings and processes of perception, but it is also a dangerous one. For words can be manipulated without mean-

ing, and often are, to the confusion of both the listener and the speaker. One can assert, "The gostak distims the doshes." This statement means nothing, but its language structure gives the impression of stating a fact. A person hearing this statement could say, "It means that the doshes are distimmed by the gostak, and that when a gostak and a dosh come together the dosh is distimmed. There is a cause and effect relationship between gostaks and doshes. Furthermore, if doshes are a species of galloons, then it follows that some galloons are distimmed by gostaks."[3] A great many arguments are precisely of this nature, especially with respect to social problems and politics. It sounds also like the recitation of a pupil who is studying a science inadequately, who has learned how to manipulate its words without having endowed them with real understanding. The remedy for this shortcoming of language is to relate the words more closely to physical reality. Unless an individual has experienced the response that is the real meaning of the word, he cannot use the word as knowledge.

Concepts. All concrete, real situations that are perceived have meaning. A rumbling noise in the driveway means that an automobile is approaching; a rock poised on the brink of a cliff means that it will fall; the lighting of a lamp bulb when the switch is thrown means that electricity is passing through it. In some instances, however, a meaning may be divested of its particular implications and treated as an entity for its own sake. It is possible to think of noise, falling, and electricity apart from the particular situations in which they occur. Such a meaning, detached from its concrete applications and provided with a name, is a *concept*. Concepts are invaluable in science and add greatly to the efficiency of perceiving and thinking. But because of their very detachment from concrete reality, they are particularly likely to cause errors in perception.

The difficulty of dealing with abstract concepts in the field of the social sciences is illustrated by a study made by Meltzer

[3] Adapted from A. Ingraham, "Nine Uses of Language," *Swain School Lectures,* 1903. Quoted by Ogden and Richards (1938).

(1925). Over three hundred elementary and high school pupils were asked the meanings of a list of important social and economic concepts. They showed an astonishing variety of disagreements and misconceptions. Some results may be cited for the high school groups. The concept "imperialism" was understood with approximate correctness by 11 per cent only, while 54 per cent thought that it pertained to the rule of a king or other high person, and 17 per cent said frankly that they did not know. Of the high school pupils, 24 per cent understood the concept "socialism" with some degree of correctness, but 25 per cent thought of it only as the designation of a political organization, 7 per cent as indicating a person who had many social duties, going to many gay parties, etc., and 4 per cent thought that a socialist is a person who wishes to overthrow the government by force. Although these are the responses of high school pupils, it is probable that adults have confused and erroneous conceptions that are similar in nature and almost as great in degree.

Variations in the significance conveyed by concept words causes great difficulty when one person wishes to express his meanings to another. People often argue and quarrel because they do not obtain the same meanings from the terms that they use. If "socialism" means anarchy to one person and a benevolent equality of opportunity to another, they cannot discuss this concept on a common basis. The method of science insists that all concepts be rigorously defined in advance of their use. Only this procedure permits language to be a medium for expressing perceptions accurately.

The Effect of Concepts on Perception. Concepts are significant not only for their own sake, but also for the influence that they have on the perception of situations. Situations are not always perceived as they actually exist, but often are modified by the verbal conceptions that an individual associates with them. Hollingworth (1928) reported a simple experiment that demonstrates this. To each of five persons was given a slip of paper, each bearing a different instruction. Then all

five stood before a tachistoscope in which was exposed very briefly a card bearing the nonsense form shown in Fig. 56. Immediately after the exposure, each person was told to write

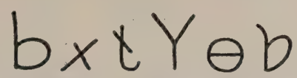


FIG. 56. The Effect of Concepts on Perception.

What is it? The perception of this ambiguous "word" varies according to the previous instructions given to the observer. The experiment is described in the text. (From H. L. Hollingworth, *Psychology,* Appleton-Century.)

on his slip of paper what he saw on the card. The results were as follows:

Instructions Given	Word Seen
1. In what various ways may a shoe be fastened?	button
2. What are the chief simple taste qualities?	bitter
3. What are the various positions in a ball game?	batter
4. What various things may be eaten on bread?	butter
5. Comparative and superlative of "good" and "bad"	better

Each person *saw* the same physical event, but each *perceived* it differently according to the related concept that was dominant at the time.

A similar result was obtained by a more elaborate experiment of Carmichael, Hogan, and Walter (1932). Twelve simple drawings were presented visually to two groups of observers (Fig. 57). For each drawing two names were chosen, each of which suggested the figure, as may be seen in the illustration. One group saw the figures exposed serially while the words in List 1 were pronounced; the other group similarly associated the drawings with the words in List 2. After the exposure, the observers were required to reproduce the drawings shown. Some typical responses are shown in Fig. 57. The "worst" drawings, those that departed most from the stimuli shown, were selected for study. Of these, an average of 73 per cent resembled the object named by the word concept more than did the stimulus figure. It is evident

that the verbal concept distorted the processes of perceiving and remembering the figure.

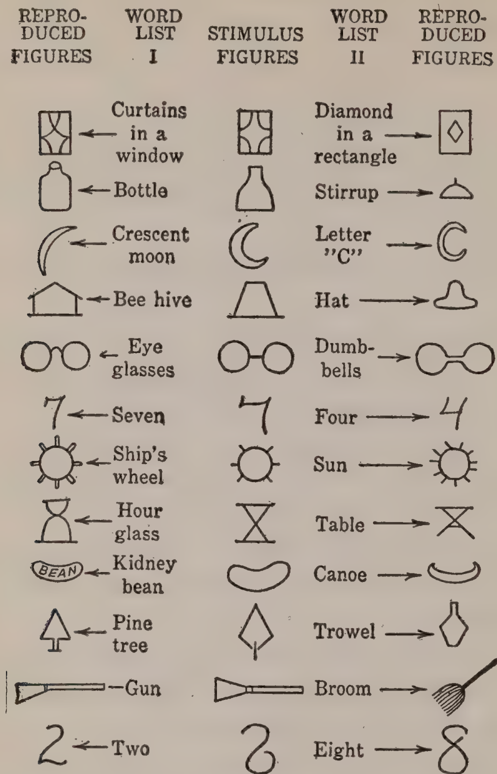


FIG. 57. The Effect of Concepts on Perception.

The figures shown in the center were exposed to one group in association with word list I, and to another group in association with word list II. Typical errors of recall given in the outer columns show the influence of the words on the memory for the figures. (From L. Carmichael, H. P. Hogan, and A. A. Walter, *J. Exper. Psychol.,* 15:73-86, 1932.)

These experiments verify a phenomenon that is seen often in everyday life. If an object is given a "good name," it will be perceived more favorably than if it is given a "bad name." That "a rose by any other name would smell as sweet" is not entirely correct. There is every evidence that it would smell

not nearly so sweet if it were called a "stinkweed." An economic policy of the government may be opposed if it is known as a "dole," whereas it would win supporters if called a "social security" measure. Propagandists seek to attach a good name to a measure that they support, and a bad name to one that they wish to defeat. Often the response aroused by the name concept causes the perception of the situation itself to be altered, so that the concept outweighs the merits of the issues involved.

Chapter IX

VISUAL EXPERIENCE

In maintaining normal adjustments to his environment, an adult human being probably depends more upon vision than upon any other avenue of sensory experience. It is appropriate, therefore, to begin an analysis of the varieties of sensory and perceptual experience with the sense of sight. Vision is not the simplest form of sensation; indeed, it is probably the most complex. But it serves as a good starting point because it is so varied and significant.

The principal characteristics of visual experience may be observed by looking psychologically at any common object, such as a closed book. First, the book possesses a certain *quality* of visual experience, being gray or red or blue. Second, this quality has a certain degree of *purity*, since one red book may be "redder" than another. Third, the book may reflect a greater or less *quantity* of light to the eye, either because of its pigment or because of the illumination in which it is placed. All these visual properties mentioned so far are relatively independent of the existence of the book itself as an object. If a portion of the cover is viewed through a hole cut in a piece of black paper, an adequate experience may be had of its visual quality, purity, and quantity. These characteristics therefore exist relatively free from the objects that possess them.

There are other visual properties of the book that are less separable from its existence as a concrete object. The *form* of the book and its *place or distance* are not so readily dissociated from it as a real thing. This is also true of the visual experience of *movement*, which is a composite of time and place.

In analyzing the nature of visual experience, this chapter considers the more abstract properties of quality and quantity first. The more object-bound properties of form, space, and movement occupy the later sections of it. This distinction is somewhat arbitrary, but is convenient. Pure visual experiences of quality and intensity have usually been classed as "sensations," while the forms, places, and movements of objects are "perceptions," but the two categories are closely related.

It must be remembered that the analysis of visual experiences is a sophisticated procedure. Things are first perceived as wholes, as the preceding chapter emphasized. A child knows a book as an object long before he can separate its components of quality, shape, or place. Experience is not made up of the elements described here. On the contrary, real whole experiences are here broken down into artificial units that do not exist by themselves. This is the usual procedure of science, for the wholes can be understood better by means of the analysis.

Visual Qualities and Quantities

The Stimuli for Vision. The physical stimulus for vision is light, either radiated from bodies such as the sun, or else reflected from objects. Light is usually regarded by physicists as an electromagnetic vibration of a certain range of frequencies or wavelengths. The visible wavelengths occupy only a very small part of the entire series of vibrations. The longest wavelengths, which are long radio waves, range up to about a million centimeters in length, while the shortest waves, cosmic rays, extend down to about .000,000,000,001 centimeter. The visible spectrum ranges from about 400 to 800 ten-millionths of a centimeter in wavelength. Just shorter than light are the ultra-violet rays, which are invisible but have important effects on animal and plant structures. Also invisible, but perceptible by the skin as warmth, are the infrared rays which are just longer in wavelength than light.

Physically, light can vary in three ways, in intensity or strength, in wavelength and in wavelength composition. The

response of the eye also comprises *three* principal variables. Limited specific bands of wavelength give sensations of color or *hue*. When mixed light of all wavelengths falls on the retina the experience is of white or gray, according to its intensity. The visual response to a very restricted wavelength has high *saturation*. Saturation is reduced by the addition of other wavelengths. *Brightness* depends chiefly upon the intensity or amplitude of the illumination, and also somewhat upon wavelength, as will be described later. The three principal psychological properties of vision are, therefore, brightness, hue, and saturation.

Brightness. The simplest visual attribute is brightness, which may be defined as visual quantity. Variations in brightness

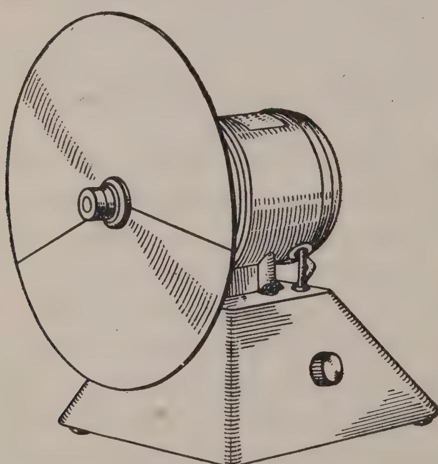


FIG. 58. The Color Wheel.

Circles of colored paper are cut along one radius so that two or more can be fitted together and rotated. When the rotation is rapid the colors fuse together and mix, because of persistence of vision.

may be observed by viewing a piece of white paper against a uniformly illuminated background. If no light falls on the paper it will appear black. If a small amount of light is allowed to strike it the paper will seem gray. The light may

then be increased by gradual steps until the paper reflects a dazzling white. The series of brightnesses thus may run from black through many grays to white. The same series can be seen by means of a color wheel (Fig. 58) on which variable black and white segments are rotated rapidly. Changing the proportions of the two disks yields a gradual transition from black, through grays, to white. Gray papers can also be prepared by using varying amounts of black and white pigments.

From the standpoint of the physical nature of the stimulus, an infinite number of brightnesses can be produced by varying the intensity in infinitely small steps. The eye, however, is not sufficiently sensitive to detect the very smallest differences in brightness. Under favorable conditions, a normal eye can distinguish about two hundred degrees of brightness between the deepest black and the most brilliant white. The series of grays is termed the *achromatic series*, since these simple visual intensities lack color. Colors also vary in brightness, of course, as is noted in the next section.

Hue. The psychological characteristic of *hue*, or *color*, depends upon the predominant wavelength of the light stimulus. White light can be separated into its component colors by prisms or other devices, yielding the *spectrum*. The shortest waves, which are bent the most by the prism, are experienced as violet. Then follow blue, blue-green, green, yellow, orange and red, as the wavelength becomes longer. Fig. 59 represents the spectrum and shows the approximate wavelengths of the principal colors. The transition from one hue to another is gradual, and a large number of intermediate hues may be distinguished. Careful experiments show that about 130 just-noticeable differences in hue can be detected in the spectrum.

A few familiar hues do not occur in the spectrum at all; they can be obtained only by mixing light from the two extremes of wavelength. Purple, magenta, and related colors are made by mixing blue and red in varying proportions. Since these hues occupy the space between red and blue continuously

without any gap, the visual hues are often represented as a circle (Fig. 60).

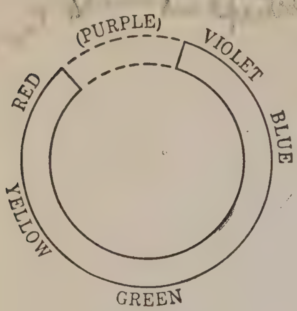


FIG. 60. The Color Circle. The spectrum can be bent into a circle, since the purples are a transition between red and violet.

The various hues differ in apparent brightness to the eye. Even when physical energies are equal, yellow appears the brightest, with green and orange next. The ends of the spectrum, violet and deep red, are much darker. Thus brightness depends somewhat on wavelength, as well as on intensity.

Saturation. The *saturation*, or *chroma*, of a color is its degree of purity. With equal brightness, fully saturated colors appear brilliant and full, while less saturated colors are weak, faint, washed-out, or unattractive. Although persons commonly recognize saturation when they observe that one leaf is "greener" than another, this quality is less commonly analyzed than is hue or brightness. In fact, brightness and saturation are usually confused, and it is necessary to distinguish carefully between them.

It is possible to vary saturation without also varying brightness by the following method. A saturated red spot of two units of intensity may be projected on a screen as a standard of comparison. Nearby, a red spot of one unit of intensity can be projected, and superimposed upon this a white light of one unit of intensity. The brightness of these spots will now be the same, namely two units. But the unsaturated spot will look quite different, being less red, more faint and pale. The same demonstration can be made with a color wheel (Fig. 58) by selecting a red disk and a medium gray disk that reflect the same gross amount of light. As the gray component is increased, the brightness does not change, since the gray is as bright as the red, but the purity or saturation undergoes a change. All hues approach gray at the limit of desaturation. Most objects in nature appear relatively unsaturated, since

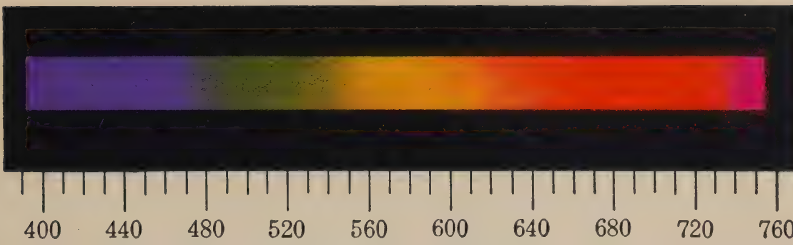


FIG. 59. The Spectrum.

White light is separated into its various wavelengths by a prism or diffraction grating, resulting in the spectrum. The hues merge gradually into one another, although certain bands of wavelengths can be designated by color names. The typical red is found at about 680 $\mu\mu$ (millimicrons), the typical yellow at 580 $\mu\mu$, green at 520 $\mu\mu$ and blue at 470 $\mu\mu$. (Modified from Duncan's *Astronomy,* Harper & Brothers, publishers.)

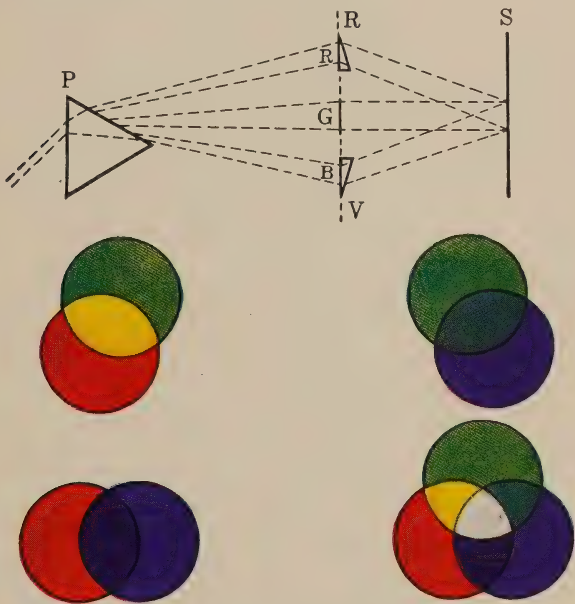


FIG. 62. Color Mixtures.

The prism *P* forms a spectrum along the line *RV*. The small prisms then bend the red and blue parts of the spectrum inward so that they partially overlap the green. Below are shown circles of the overlapping colors and the resulting mixtures. Green and red yield yellow; green and blue give blue-green; and blue and red make purple. Green, red, and blue combine to make white. Certain lenses, slits and other accessories necessary for the operation of the apparatus have been omitted from the diagram.

they reflect light of more than one wavelength. The predominant wavelength determines the color of the object, and the mixed wavelengths reduce its saturation.

If brightness is varied saturation usually changes also. If to our two-unit red light we add two units of white light, the total brightness is doubled, but the saturation is reduced. Mixing white with a pure hue gives a *tint*, which is brighter but less saturated. Pink is a tint of red. A *shade* is obtained by mixing black with a hue. Since most practical so-called blacks are really very dark grays reflecting a little mixed light, shades are both darker and less saturated than the pure hue.

The Color Solid. The psychological properties of visual quality and quantity can be represented conveniently by a three-dimensional diagram (Fig. 61). The central circle is the hue circle of Fig. 60 on which the hues are represented by letters. The nonspectral part is dotted. The circle is tilted to show that yellow is inherently brighter than blue. The central axis is the achromatic series, with white at the top, medium gray at the center, and black below. Variations in saturation are represented by the inner volume of the solid. Thus along the line B-Gy, blue becomes less and less saturated until it arrives at gray. The tapering top and bottom indicate that saturation always decreases as brightness becomes either greater or less.

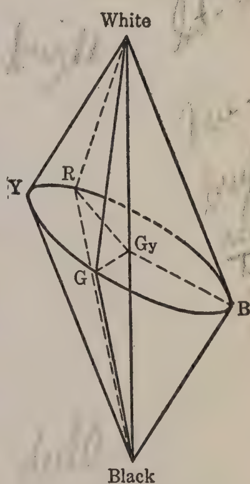


FIG. 61. The Color Solid. The circle at the center represents the spectrum of saturated hues, as in Fig. 60. Medium gray is at the center of the circle, white is at the top of the double cone, and black is at the bottom.

Stimulus Mixture. If superimposed red and yellow lights are viewed, the resulting experience is orange. Mixing blue and green gives a blue-green, sometimes called "peacock." As was said before, red and blue yield purple. In general, adding two colors in the eye gives a hue intermediate between them. These

effects may be shown by superimposing spots of spectral color on a screen (Fig. 62) or by rotating split disks of various colors upon the color wheel.

Certain pairs illustrate another principle, however. When blue and yellow are mixed by superimposing lights or by rotating these disks on the color wheel, the result is white or gray. Similarly, red and a bluish-green, or green and a purple, yield white or gray when mixed in the same manner. In general, each hue has some other hue with which it may be mixed to give white or gray. Each hue of such a pair is the *complementary hue* of the other. The fact that *two* hues may give white, whereas ordinary white daylight is composed of *all* hues, is of great importance in explaining color vision, as will be shown later. Red plus green yields yellow. These hues are not, therefore, complementary, but both disappear when they are mixed.

One of the most significant facts of color mixture is that any hue can be reproduced by mixing *three* hues in proper proportions. Various proportions of blue and green give blue-green, red and green when mixed give yellow, red and blue give violet. Three colors that can yield all other hues are *blue*, *green*, and *red*. While these three are most commonly employed, there are many other sets of three hues that also give all other colors, such as yellow, blue-green, and magenta. Each such set of three hues is a "triad" and is located at three equidistant points around the color circle.

Primary Hues. Physically, there are no primary hues, since every spectral hue results from a unique wavelength of light. There is no physical reason for giving one wavelength a dignity denied to another by calling it "primary." A long-standing tradition in popular speech, art, and older periods in the history of psychology, however, demands that certain hues be designated as primaries. Primaries have been chosen according to two points of view both of which have some merit. If the reasons for the two classifications are clear, no confusion should be experienced.

In order to *produce* all hues, *three* colors are the minimum

essential number. Of all possible triads, *red, green,* and *blue* are usually chosen as the primaries. This choice is justified by the experimental fact that these three colors will yield all others when properly mixed, and by the introspective observation that they appear pure. They do not seem to be made up of anything else of a simpler nature, whereas all other triads, such as magenta, blue-green, and yellow, contain at least one or two colors that are obviously composite.

In order to *describe* all hues, *four* color names are the minimum essential number. By common usage these are *red*, *yellow, green,* and *blue*. Violet can be described by calling it a reddish-blue, but yellow, unlike other mixtures, looks unique. Yellow can be made by mixing red and green, but these two components are not apparent in the product. Yellow does *not* look like a "reddish green" or a "greenish red." Indeed, a "reddish green" or a "greenish red" is quite impossible to imagine. Yellow has often been called a primary by persons who are interested in the psychological description of visual sensations.

It is absurd to argue which is the "correct" number of primary hues, three or four. Three is correct from the point of view of color-mixing, four from the point of view of color-naming. Both systems are therefore useful in their proper spheres.

The statements made here may seem to contradict the reader's experiences with his paint box. When ordinary water color or oil pigments are mixed, blue and yellow seem to give green, while red and green seem to give a muddy brown. Blue and yellow pigments yield a green pigment only because they are impure. "Blue" paint really reflects a large amount of green light as well as blue. "Yellow" pigments also usually reflect green as well as yellow. Hence when these two are mixed, the real blue and yellow cancel each other as white, revealing the green that was in both all the while. Also, brown is an unsaturated yellow, hence the paint box does demonstrate that red and green give yellow. The three "primary"

colors of the artist that he is likely to call "red," "blue," and "yellow" are actually nearer magenta, blue-green, and yellow. These three are the *complements* of the three primaries agreed upon by most physicists and psychologists. They are a satisfactory triad for practical work, however, and will, of course, yield all other colors.

The Mechanisms of Vision

The Eye. The receiving apparatus for vision is the eye. It consists of elaborate accessory mechanisms which bring an image to focus, and the *retina* which contains the sensitive nerve endings or receptors proper. The eye (Fig. 63) is enclosed in the tough white *sclerotic* coat, which has a transparent portion at the front called the *cornea.* Light passes through the cornea, the outer chamber of *aqueous humor*, the *lens*, and the large chamber of *vitreous humor*, before reaching the retina. These media serve to refract the light, or bring it to focus. The amount of light entering the eye is controlled by the *iris*, a muscular diaphragm which contracts when light is intense and dilates when it is dim. This is a reflex adjustment. The opening in the iris is the *pupil.*

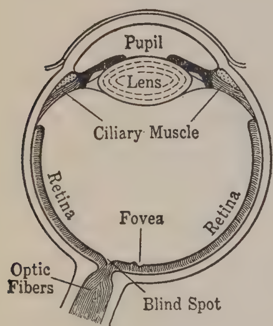


Fig. 63. A Cross Section of the Eye.

The human eye focuses on near and far objects by changes in the curvature of the lens. The *ciliary muscle* around the lens causes it to become more convex when looking at near objects, and less convex when fixed upon far objects. These changes keep a sharp image on the retina. Each eye is moved in its orbit by six external muscles. Normally, the muscles of the two eyes work together, converging the eyes to look at near objects. The accommodation of the lens is controlled by reflex circuits closely allied to those controlling the external

movements, so that the accommodation and convergence of the eyes are performed in one reflex act.

The Retina. The receptors for vision lie in the *retina*, a thin layer of sensitive cells on the inner surface of the eyeball (Fig. 64). Light falling on the retinal receptor cells sets up nerve impulses which are carried to the brain. The chemical

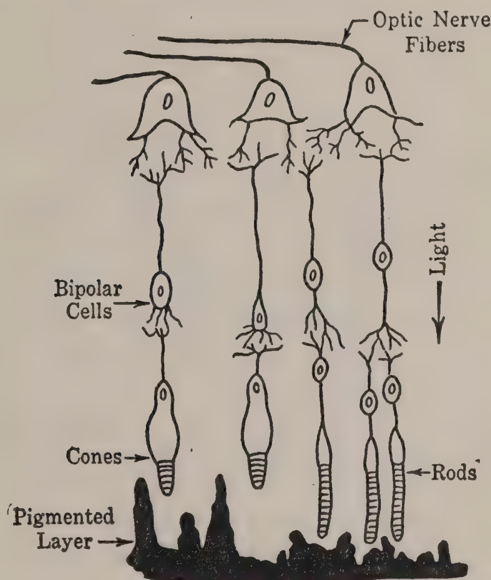


FIG. 64. A Microscopic Cross Section of the Retina.

The light passes through the outer layers of cells before reaching the sensitive rods and cones. The neural impulses start from the rods and cones, go to the bipolar cells to the optic nerve cells, and are conducted to the brain by the optic nerve fibers.

action upon the retinal cells is analogous to the bleaching of a color by light, but is much more rapid.

The retina is a very complex neural structure consisting of several layers of cells. The true receptors are the outermost layer of cells against the coat of the eye, and the light has to pass through the other translucent layers of cells to reach them. There are two kinds of receptor cells, the *rods* and the *cones*. The cones function only in bright light and are capable

of color differentiation. The thinner rods function mainly in dim light and cannot discriminate colors. For this reason, everything appears gray at night, even when there is enough light to see a path and to distinguish objects. The separate functioning of the rods and cones is termed the *von Kries "duplex theory,"* after its discoverer. The most sensitive spot in the retina is the *fovea*, which is located at the center and contains only cones. The outer portions of the retina, the *periphery*, contain fewer cones and more rods. Hence vision in dim light is best in the periphery, but color vision is best at the center. The rods are also quite sensitive to movement, which can be seen very well by the periphery of the retina.

The neural impulses are transmitted from the rods and cones to the *bipolar cells*, thence to the *optic nerve cells* whose axons leave the eye as the optic nerve. There are also lateral neurons connecting adjacent areas of the retina which are important in the explanation of certain visual phenomena. A small area of each retina, the *blind spot*, is insensitive to light. This is the point at which the optic nerve fibers leave the eye by piercing the retina, the fibers being gathered on the inner surface. Since it contains no rods or cones, the optic nerve itself is not sensitive to light. The blind spot may be found by fixating an X on a piece of paper with the right eye, and exploring to the right with a pencil. A surprisingly large area will be found in which the pencil point disappears.

The Visual Brain. The optic nerves from the two eyes join at the *optic chiasm*, or "crossing," soon after leaving the eyes (Fig. 65). At this point the fibers are redistributed, those from the left side of both eyes going to the left side of the brain, and those from the right to the right side. Since the eye, like any camera, inverts the image on the retina, we thus see to the left with the right side of the brain and to the right with the left side. This redistribution of fibers occurs only in animals which, like man, see to the front. In many lower animals, such as cattle which have the eyes on the sides of the head, the right eye fibers pass undivided to the left side of the

brain. This reversal is characteristic of most neural structures, as has been described in Chapter III.

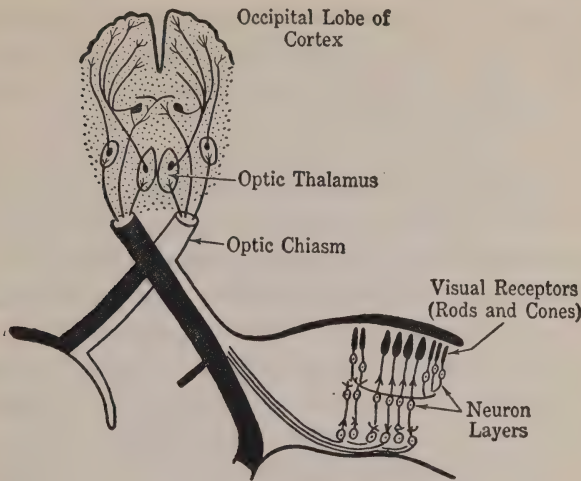


FIG. 65. The Optic Tracts.

From the retina (greatly enlarged) the optic fibers go to the thalamus and to other intermediate brain centers, and finally to the visual cortex in the occipital lobes of the cerebrum. Note that the fibers from one side of both eyes go to the corresponding side of the cortex.

All optic nerve fibers end in the thalamus, where synaptic connections to new fibers bring the impulses to the *visual cortex.* The visual brain areas are located at the back of the cerebrum in the parts of the occipital lobes which lie adjacent to the great fissure that separates the hemispheres. Some visual impulses are short-circuited at lower reflex centers near the thalamus, providing for the reflex accommodative functions. Only when the visual neural impulses reach the cortex does vision occur. Damage to this area causes blindness just as surely as does damage to the eye itself. The visual cortex is richly provided with fibers running between its halves, making possible the coordinated use of the eyes. It also has connections with all other important brain centers which function in the visual control of general bodily movements.

Some Other Characteristics of Vision

Persistence of Vision. A momentary visual stimulus causes a retinal response that persists for a brief interval after the stimulating energy has ceased. The retinal cells continue to act for a time after they have been stimulated. Thus a bright lamp moving very rapidly across the field of vision appears as a streak of light. The usual neon lamp flashes 120 times per second, yet the eye sees it as a constant light. This is because another stimulating flash occurs before the effect of the first has subsided. Visual lag causes some inefficiency in vision, for it makes rapidly moving objects appear blurred. It is essential to some perceptions, however, especially in viewing motion pictures, which are intermittent views shown at a rate of from 16 to 24 per second. If the rate of interruption of an intermittent stimulus is too slow, falling below 10 or 12 stimulations per second, an unpleasant *flicker* appears. The brighter the interrupted stimulus, the higher is the frequency at which flicker will be seen. This fact is sometimes used in measuring the intensity of light.

After-sensations. Visual persistence or lag lasts only about one-half a second at the longest, but a more enduring after-effect of a visual stimulus may be observed; this is called the *after-sensation.* After-sensations are of two kinds, positive and negative. A *positive after-sensation* of a light is bright, and that of a color is of the same hue. The *negative after-sensation* of a light stimulus is dark, and that of a color is usually of the complementary hue.

Positive after-sensations are secured most easily if the original stimulus is very intense and brief, and if the field upon which the eye is fixed immediately afterward is relatively dark. For example, one can take a quick glance at the sun, and then look at a dark background. A bright orange spot, the positive after-sensation of the sun, is usually seen quite clearly for some time.

Negative after-sensations are obtained most efficiently by

a long stimulation from a less intense object, the after-field of eye fixation being light. If an individual looks intently at a small white square of paper on a dark background for about thirty seconds and then shifts his eyes to a large white expanse, he sees a gray shadow of after-sensation. Or he may fixate a red postage stamp for half a minute and then look at a white paper. A bluish-green after-sensation of the red stimulus usually appears.

Positive and negative after-sensations are closely related. If a long observation is made of the after-effects of a fairly bright stimulus, a succession of after-sensations may be seen, positive, negative, positive, negative, and so on. A positive after-sensation may be changed immediately to a negative one by shifting the gaze from a dark to a light background, and vice versa. Often it takes practice to see after-sensations at all, since they are constantly ignored in everyday life as "not real." They are true physiological phenomena, however, and not imagined effects.

Visual Adaptation. In addition to the pupillary regulation of the amount of light that enters the eye, the retina itself adapts to various degrees of illumination. If one steps from a brightly lighted room into a dimly lighted one, it seems very dark, but after a time he can distinguish objects quite well. On entering a brightly lighted place again, the illumination is dazzling until the adaptation has taken place. A bright light reduces the responsiveness or sensitivity of the receptors, while a dim light increases it to secure optimum vision. It takes a long time for the retina to adapt completely to the dark, about a half hour being required for full adaptation to an entirely darkened room. Adaptation to light is much more rapid, taking only a few minutes.

Adaptation to specific hues may also be observed. Continued fixation on a red spot causes it to become less and less saturated, until it approaches gray. When the eye is adapted to one particular hue, other unrelated hues are not affected, but may be seen in their full brilliance.

Visual Contrast. A small medium gray spot appears much darker on a white background than on a black one, an effect that is called *contrast.* Contrast also appears in color sensation. A gray spot surrounded by red takes on a blue-green tinge. In fact, any brightly colored stimulus tends to induce a trace of its complementary hue in adjacent areas. Pairs of complementary hues are enhanced by contrast. Thus if red and blue-green are placed close together, each appears more saturated because of the presence of the other. Many devices used in painting, costume design, and advertising depend upon contrast. Since contrast is experienced immediately upon viewing the stimulus, it cannot be due to fatigue or to the formation of after-sensations. It is caused by the interaction of adjacent visual neurons, either in the retina itself or in the visual cortex.

Retinal Zones. The retina is not equally sensitive over its entire area. Shapes and forms are perceived best at the fovea,

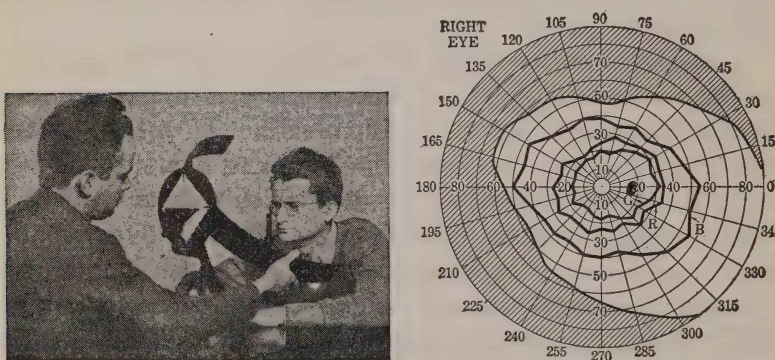


FIG. 66. The Measurement of Retinal Zones.

At the left is a perimeter in use, measuring the color zones of the retina. At the right is a perimeter chart for a normal right eye. The unshaded area is sensitive to white. The outer limits of sensitivity to blue, red, and green are shown by the heavy lines labeled *B, R,* and *G.* The blue-sensitive area is large, but the *R* and *G* areas are smaller and almost coincide.

and are somewhat less clear in the margins or periphery. Movements are seen even in the extreme periphery. The color sensitivities of the retinal zones vary quite uniformly (Fig.

66). All hues can be perceived at the center. As a green stimulus is moved from the center to the margin of vision, it gradually loses its greenness, becomes yellow, and then gray. Red also changes through yellow to gray. Blue and yellow are visible farther out in the periphery, changing to gray without transition through another hue. The exact determination of the retinal zones varies with the brightness, saturation, and size of the test object. Stimuli that are more intense, more saturated, or larger are visible in their true color farther out in the periphery. The color zones of the retina indicate that there are separate receptive processes for various colors, and that these are not equally distributed.

Color Blindness. Not all persons see hues equally well even in the center of the retina. About four per cent of men and about one-tenth that number of women suffer from color blindness, of which there are several types. Color blindness is caused by the absence or inefficiency of some of the cone receptors of the retina. It is usually congenital and cannot be cured.

The most common type of color blindness results in a failure to distinguish *red* from *green*. These two colors are especially likely to be confused if they are faint and unsaturated. Two subtypes of red-green color blindness have been identified. The so-called *green-blind* person confuses red, yellow, and green since these look about alike in hue, differing only in intensity. A certain green looks colorless to him. The less common *red-blind* type confuses red, yellow, and green even more than the green-blind. Furthermore, he sees nothing at the extreme red end of the spectrum, his spectrum being shorter than that of a normal person. For practical considerations, these two types are alike in that they cannot distinguish red and green accurately. Very precise laboratory tests are necessary in order to distinguish the particular subvarieties of color blindness. The best available evidence indicates that red and green appear to a red-green color-blind person about as an unsaturated yellow does to the normal eye.

A third type of color blindness, *blue-blindness,* is so rare

that its very existence is a little uncertain. It seems usually, or even always, to be due to a disease of the retina, or to a yellow pigmentation of the lens that filters out the blue rays. Total color blindness, which is also uncommon, consists of an absence of all hues, everything being seen in shades of gray.

There is a continuous transition from color blindness through *color weakness* to normality. The color-weak person has no difficulty in discriminating between bright stimuli such as traffic lights, but is troubled by distinctions between delicate pinks and light greens. In fact, all color blindness is comparative and many slightly color-blind persons do not know of their deficiency until precise tests are applied.

A number of tests are used to detect color blindness and to measure its type or extent. One of the best tests is the Ishihara Plates. These cards contain, for example, numerals made up of faint red dots on a background of light green dots. The normal eye can see the number clearly, but a color-blind individual cannot distinguish the figure from its background. The Holmgren Worsteds Test consists of small skeins of wool that must be matched with a light green, a pink, and a deep red standard. Typically, a color-blind person puts yellows and pinks with the green; greens, yellows, and whites with the pink; and browns with the deep red. The Ishihara Test is more efficient for detecting cases of slight color weakness, but the Holmgren test is more similar to the situations encountered in everyday life.

Actual and Conceptual Vision. All normal vision, and all experiments in vision, are complicated by the fact that persons usually report experiences with colors as they think they should be, rather than as they actually meet the eye. A white dress worn by a girl sitting in the shade is reported as white by the naïve observer, whereas it really reflects a variety of grays. The "white" in this case may be termed a *conceptual color* for it is what the person conceives the object to be. If one were to paint a picture of the girl, a pure white representation of the dress would be garish and unreal. The artist, who has

trained himself to see things as they are, uses grays in the dress and deeper grays in the shadow, achieving a really representative result. The same phenomenon occurs with hues. An individual will perceive a blue book as the same blue under a variety of illuminations, whereas it really reflects many different intensities and even different hues in various lights.

Conceptual vision illustrates a very common characteristic of human nature. Persons tend to perceive things *in relation to their surroundings*. They make allowances for changes in the general illumination, and see things according to their *past experiences* with the objects, as well as according to their present sensory impressions. To separate the present scene from all of one's experiences with it in the past is quite difficult. Artists, and psychologists who are trained to make introspective observations of sensations, are among the few persons who ever have pure visual sensations uninfluenced by expectation or prejudice.

Explanations of Color Vision

Several theories have been proposed to explain color vision, none of which is entirely satisfactory. These theories should be regarded as useful approximations of the truth, to be revised when further research has extended our knowledge of the visual processes.

The Young-Helmholtz Theory. The earliest modern theory of color vision was suggested by Thomas Young (1801) and elaborated by Helmholtz (1859). It is based chiefly on the observation that all colors can be produced by the mixture of three hues. The Young-Helmholtz Theory therefore supposes that there are three kinds of cones in the retina which are sensitive principally to red, green, and blue (or violet) respectively. Color mixtures are explained adequately by this theory, since mixtures act upon more than one type of receptor. Purple, for example, excites both the red and blue receptors, whose impulses are combined in the brain to give the composite sensation. Equal stimulation of all three recep-

tors gives white. Pairs of complementary hues give gray or white, since the complement of any hue consists of the colors to which the other receptors are sensitive. Negative after-sensations are explained in terms of receptor fatigue. If the red receptor is stimulated, for example, it becomes fatigued or adapted. White light then causes a greater response from the blue and green receptors than from the fatigued red receptor, resulting in the blue-green negative after-sensation.

The principal weakness of the Young-Helmholtz Theory lies in its failure to account for some of the peculiar properties of *yellow* and *white*. The color zones of the normal retina cannot be explained by this theory. As has been described, both red and green appear yellow and then gray as they are moved from the center of the field of vision to the periphery. In the intermediate zone, therefore, yellow can be seen but not red or green. In the extreme periphery white is perceived, but red, green, or blue cannot be. These observations contradict a theory that provides for yellow only as a mixture of red and green, and white only as a mixture of all three colors. Color blindness also gives trouble to the Young-Helmholtz Theory. The common type of color-blind person can see yellow, but cannot distinguish red or green. The linkage of red and green, but not blue, in common color blindness is also poorly explained by this theory.

The Hering Theory. The color theory of Hering (1888) assumes that there are six primary visual elements, grouped in three pairs. One receptive process of the retina is sensitive to white and black, another to yellow and blue, and a third to red and green. Hering supposes that black is a definite sensation, not an absence of sensation. Complementary hues are explained adequately by this theory. For example, blue and yellow neutralize each other in the blue-yellow receptive substance, hence only their brightness (white) remains to be sensed by the white-black process. After-sensations offer no difficulty to the theory. After responding in one way, such as blue, the receptive substance reacts to its opposite response, such as yellow. Color mixing can also be explained.

Hering's theory has some serious shortcomings, however. In order to make red and green complementary hues as the theory demands, Hering selected a "primary" red and a "primary" green both of which look definitely bluish and nonprimary to ordinary observation. Also, the theory cannot account for the known subtypes of color blindness. The Hering theory also requires six elementary processes; the other theories explain as much with the assumption of three or four.

The Ladd-Franklin Theory. Another explanation of visual action has been offered by Ladd-Franklin (1929). This theory supposes that the retinal structures have been modified in the

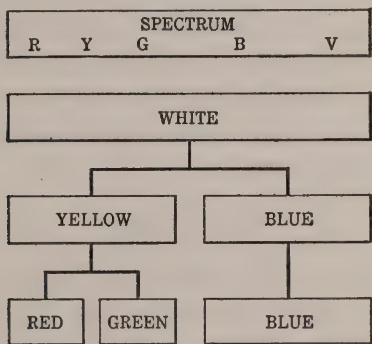


FIG. 67. The Ladd-Franklin Theory of Color Vision.

In the most primitive stage of evolution all retinal cells give the same response (white) to all wavelengths. In the second stage, some cells are sensitive to the short waves (blue) and some to the long waves (yellow). In the third stage, the yellow-sensitive cells have become differentiated further, giving red and green sensations.

course of evolution. The most primitive response is of white, caused by light of any or all wavelengths. Later a differentiation of a light-sensitive substance occurred, giving a discrimination of the spectrum in two parts, the long waves (yellow) and the short waves (blue). Further evolution caused the yellow-sensitive substance to divide into two substances which detect the longest waves (red) and the medium waves (green). This scheme is diagrammed in Fig. 67.

The Ladd-Franklin Theory amounts to the same thing as

the Young-Helmholtz Theory with respect to the central portion of the normal human retina, assuming the mixture of red, green, and blue. But the Ladd-Franklin Theory gives a clearer account of the psychological uniqueness of yellow and white. It also explains the retinal zones by supposing that the center of the retina is in the third stage of evolution of red, green, and blue sensation, the intermediate zone in the second stage of blue and yellow sensation, and the outer zone in the first stage in which primitive cones give sensations only of gray and white. The connection of red and green in color blindness is well accounted for by the assumption that these hues are descended from the same source, namely, yellow.

One theory of vision explains some phenomena more clearly, and another theory excels in explaining certain other observations. It is probable that all theories are partially correct, and that they will be reconciled in some more comprehensive theory to be evolved in the future.

Visual Form

The Basis of Form. The forms of objects are perceived by the projection of images upon the retina. Since the retina consists of a number of small but separate receptors, the image is really a mosaic of tiny dots of perceived gray, white, or color. The smallest size of object that can be seen determines the "resolving power" of the eye; this depends upon the efficiency of the lens system as well as on the size of the receptors. An object must make an angle of one minute (1/60 of a degree) at the eye in order to be seen clearly in the most sensitive portion of the normal retina. Thus two lines can just be seen as two if they are about 1/100 of an inch apart at a distance of three feet, or about 1/3 of an inch apart at a distance of 100 feet. Lines closer together fuse into one.

The eye is a system of convex lenses, and therefore, like a camera, it projects an image that is inverted and also transposed as to right and left. The fact that persons see objects

upright when the retinal image is inverted is not hard to explain psychologically. Concepts of up, down, right, and left depend ultimately upon experiences other than vision, especially touch, weight, and movement. When the infant is learning to use his eyes, movements and contacts that are "up" always are accompanied by a certain visual pattern, and those that are "down" convey the opposite visual impression. Up and down, and also right and left, are spatial concepts with which one *learns* to coordinate one's visual experiences. In one experiment Stratton (1896) wore lenses that inverted the light rays entering one eye, and hence threw an *erect* image on the retina instead of the usual reversed one. The other eye was blindfolded. With these lenses, everything appeared upside down at first, and he experienced great difficulty in the coordination of movements. After a week of practice, however, he became skillful in interpreting his new visual experiences and in regulating his visual-motor coordinations. Upon removing the glasses there were a few hours of confusion again, but the lifelong visual habits soon reappeared. Erect vision is therefore believed to be due to the formation of habits which coordinate seeing with movement and contact.

Defects of Vision. The visual perception of clear forms is prevented by a number of common defects of the optic mechanisms. If the lens system of the eye does not focus images correctly upon the retina, blurred vision results. The most usual defects of this type are *hyperopia*, *myopia,* and *astigmatism.* The hyperopic, or "farsighted," eye can focus distant objects properly, but cannot focus near objects without an excessive effort of accommodation. The myopic, or "nearsighted," eye sees very near objects clearly, but cannot focus in the distance. Astigmatism is an irregularity in curvature of the lens system, usually the fault of the front surface of the cornea. An astigmatic cornea has greater curvature along one axis than along some other; it is not perfectly spherical. This causes a distorted image. It also often results in discomfort arising from the

struggle of the muscles of accommodation to compensate for the irregularity. Most cases of astigmatism may be corrected by lenses having curvatures opposite to those of the defect of the eye.

Hyperopia and myopia require a more extended explanation. Considered as a physical object, the lens of the eye must be more convex to focus a nearby stimulus, and less convex to focus a distant one. In the physical sense, therefore, the near-sighted eye is too long or has too convex a lens, while the far-sighted eye is too short or has a lens that lacks sufficient convexity. The usual corrections for these defects are made by supplying concave spectacle lenses to counteract the excessive convexity of myopia, and fitting convex spectacle lenses to supplement the insufficient convexity of hyperopia.

The eye is not a stationary physical object, however, but a living and functioning organ. The convexity of the lens is determined not only by its inherent shape, but also by the action of the muscles of accommodation, the *ciliary muscles*, to which reference has already been made in the description of the eye. These muscles act in close reflex relationship with the external muscles of the eye which converge the eyes to look at close objects. The farsighted person, considered physiologically rather than merely physically, has to exert such effort to innervate the ciliary muscles strongly enough to focus the lens on nearby things, that discomfort usually results. The near-sighted person, on the other hand, has too great a contraction of these muscles, a kind of muscular spasm, so that he cannot relax them sufficiently to see far objects clearly.

Unless properly treated, many cases of myopia may become progressively worse. One cause of progressive myopia is illustrated by the following description. If a nearsighted person has to hold a book too close while reading, the convergence is also too great, that is, the eyes are strained to point inward. This causes an even greater reflex contraction of the lens, since accommodation and convergence tend to keep together. A

vicious circle is set up, for the ciliary muscles become more and more tense and thereby increase the myopia. Myopia can often be relieved by suitable exercises for the eyes which inhibit the stimulation of the erring reflexes and retrain them to function normally. The reeducation of the eye reflexes is an important application of psychology to optometry. Similar procedures are helpful in many cases of squint or "cross-eyedness" which is usually a defective functioning of the muscular reflexes of the eyes. The correction of visual defects by reeducation is called *orthoptic training.*

Factors Influencing Visual Form. What an individual sees is not determined solely by the images that fall upon his retina. A number of other factors influence the perception of form, shape, and number. Some of these are inherent in the process of perceiving, while others are due to the habits created by past experience. A few of the more important of these factors will be listed and described briefly.

The number of separate things that can be perceived at once is very limited. This fact is demonstrated by exposing for brief intervals (such as one-tenth of a second) cards on which are printed dots, letters, or simple drawings. The average person can state correctly the number of dots seen only up to a limit of six or seven. Only about four disarranged letters can be reproduced correctly after one glance (Fig. 68). These experiments show that the *span of apprehension* of separate objects is surprisingly small. One way in which this limitation of perception is overcome in real life is by making a number of quick successive glances. Thus, while driving an automobile one sees very little at one instant, but may comprehend much from a series of quick impressions that are perceived as parts of the total situation.

The limits of a single experience are further overcome by the tendency to *combine the elements of experience into groups, "wholes," or "configurations."* If dots are arranged in a geometric pattern, sixteen or twenty-five can be counted correctly

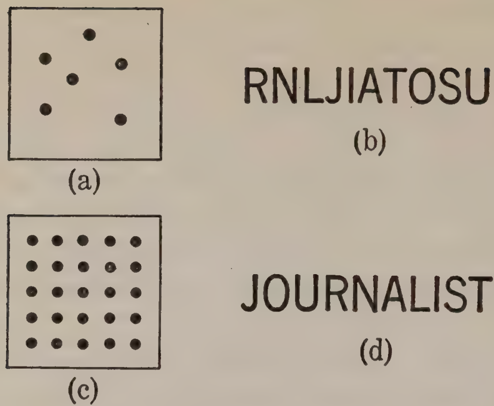


FIG. 68. The Span of Perception.

When shown for a very brief interval, as in a tachistoscope, only about six dots (*a*) can be seen, or about four disarranged letters of a set (*b*). When the material is arranged in a pattern or in a meaningful sequence (*c*, *d*), however, much more can be comprehended in one glance.

in one brief glance. This is possible because the dots are not seen as individual items, but as "four rows of four dots" or "five rows of five." The *group* thus becomes the unit, and as many groups can be perceived as can separate entities. If letters spell a word, ten can be apprehended without difficulty, as compared to four when they have no coherence. This principle operates in all our everyday experience. We see a man, a store, or a forest as a unitary experience, not just as an enumeration of separate parts.

Some factors favorable to the formation of perceptual groups have been analyzed. Three that are inherent in the arrangement of visual material may be designated as proximity, similarity, and continuity. *Proximity* is illustrated by the tendency to group stimuli that are near together. Thus in Fig. 69 (a) appears to be four pairs of dots, not just eight dots. The factor of *similarity* is shown in (b) of the same figure, in which items of similar shape seem to stand together. *Continuity* is perhaps the most common of these factors. In (c) one sees a wave made up of dots rather than a string of single dots,

and a six-pointed star, not a collection of straight lines or of triangles. The elements of a continuous whole thus subordinate themselves to the whole itself.

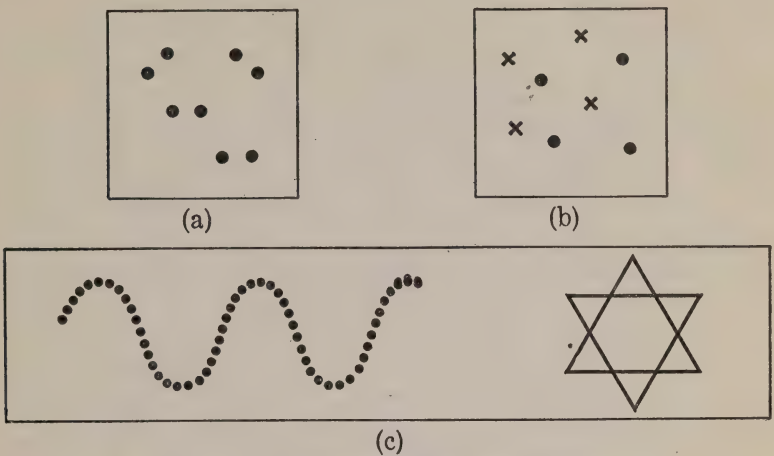


FIG. 69. The Formation of Perceptual Groups.

(a) The effect of proximity; (b) the effect of similarity; (c) the effect of continuity.

In addition to the forms inherent in the stimuli themselves, many others are added by familiarity or habit. A locomotive is seen as one object not only because its parts possess continuity, but more importantly because they have always occurred together in the experience of the observer. The occurrence together, or conditioning, of situations thus affects the perceptual responses to them just as it also modifies the muscular or behavioral responses in the manner pointed out in Chapter V. To cite another example, printed words have visual coherence only after a person has had experience with them. Habit explains the superior perceptual value of a word over a collection of unrelated letters.

The organization of visual experience into wholes is often described by the terms *figure* and *ground*. The *figure* is the pattern that is clearly and coherently perceived at the moment. The rest of the perceptual field becomes *ground*, or back-

ground, upon which the dominant grouping appears to be placed. In any situation the connectable elements to which one pays the closest attention form a perceptual figure, which is seen upon a less keenly sensed ground. The perceptual figure shifts frequently, even without the aid of movements of the head or eyes, as one part and then another of a complex situation becomes perceived clearly.

When a situation permits two organizations or groupings, persons tend to respond to only one of them at a time. An object seen hazily through a fog may be taken for a distant smokestack; then suddenly one realizes that it is a telephone pole located much closer at hand. After this change in percep-

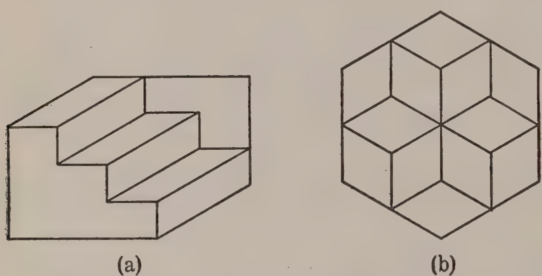


FIG. 70. Ambiguous Figures.

(a) Are you looking at the top or the bottom of the flight of stairs? (b) Are you looking at the cubes from above or from below?

tion has occurred, it is very difficult to make the object look like a smokestack again. This selective feature of perception is illustrated most clearly by *ambiguous* or *reversible figures* that are drawn so as to be capable of more than one interpretation. The drawings in Fig. 70 consist only of lines drawn in a plane, yet our habit of regarding such representations as three-dimensional objects leads us to see them as a flight of stairs and a nest of cubes. The figures fluctuate, appearing first as one arrangement and then as another. That an ambiguous figure can be seen in two ways is inconsequential; it is drawn so that this is inevitable. The important psychological phenomenon is that it can be seen *only one way at a time.* This selective

process of perception occurs not only in the special diagrams that show it most clearly, but constantly in real life situations.

Two further illustrations of the general tendency to see forms as wholes or figures can be cited. If figure and ground are interchangeable, they may be reversed from time to time, as in Fig. 71. But one pattern or the other is always the dominant figure. Another example is found in *binocular rivalry* (Fig. 72). If two incompatible figures are presented, one to one eye and one to the other, they do not fuse, but alternate. The horizontal and vertical stimuli do not yield a uniformly cross-hatched appearance, but fluctuate in the field of vision.

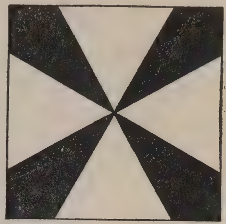


FIG. 71. Reversible Figure.

This object is reversible as to "figure" and "ground." A white Maltese cross may be seen on a black ground, or a black cross may appear as the dominant figure on a white ground.

Illusions. Some visual perceptions that do not check with other sensory experiences or with measurements are termed *illusions.* Illusions occur in normal experience, but are seen most clearly in drawings prepared with the intention of deceiving the observer.

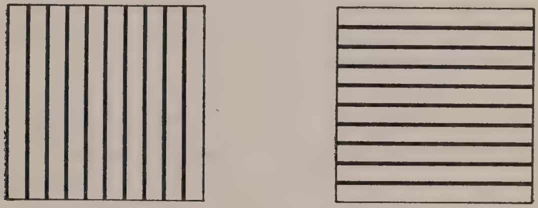


FIG. 72. Stimuli for Binocular Rivalry.

This figure is best viewed by a stereoscope which presents one square to each eye. It may be seen without a stereoscope by holding the page about four inches from the eyes and relaxing the convergence of the eyes as if to look at a distant object. Three images are seen, the "middle" one being the binocular image. The cross lines do not fuse, but fluctuate.

Many illusions are caused by the tendency to *perceive wholes* rather than parts, which was discussed in the preceding section.

The best-known example of this type is the Müller-Lyer illusion (Fig. 73). The line terminated by the diverging oblique lines looks longer than the one ending in the converging lines because the judgment of length is biased by the *area* covered by the entire figure. The parallelogram illusion, which is even more striking in its effect, is based on the same principle and may be regarded as a variant of the Müller-Lyer figure.

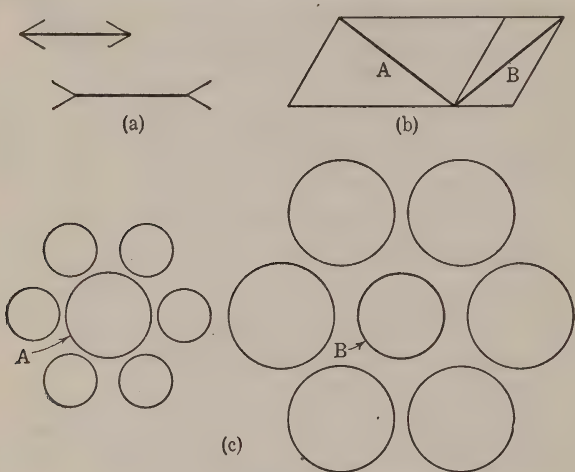


FIG. 73. Visual Illusions—I.

(a) The Müller-Lyer illusion. Which line is longer? (b) The parallelogram illusion. Are the diagonals *A* and *B* of equal length? (*c*) The contrast illusion. Which central circle looks larger, *A* or *B*?

Somewhat the opposite effect is obtained in the *contrast illusion.* This illusion also is based on the influence of adjacent figures, but occurs when several *wholes* are compared rather than when the part is influenced by the whole, as in the preceding case. In Fig. 73 (c), circles A and B are really of the same size. Perceptual contrast occurs frequently in ordinary experience. An average-sized man looks tall when standing among short men, but appears short when surrounded by men who are tall. A picture that is strikingly attractive when hung with poor ones looks mediocre when compared to masterpieces.

Another type of illusion that depends upon an effect produced by surroundings is illustrated by the Poggendorf, Zollner, and Wundt figures (Fig. 74). All of these concern the influence of lines that are oblique to one another. In the Poggendorf figure the interrupting parallel lines cause the angle of the oblique line to be estimated erroneously. In the Wundt

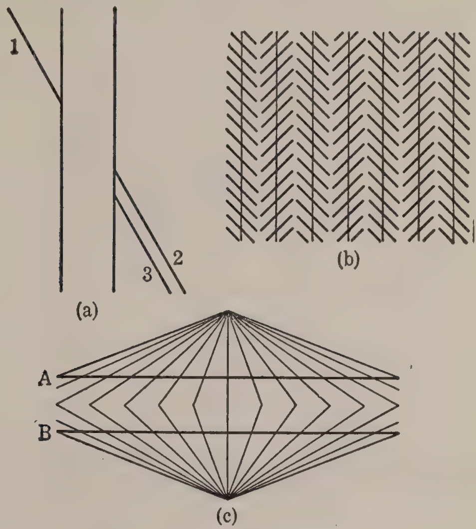


FIG. 74. Visual Illusions—II.

(a) The Poggendorf illusion. Is the line *1* continued as line *2* or *3*? (b) The Zollner illusion. Are the vertical lines parallel or do they converge? (c) The Wundt illusion. Are the lines *A* and *B* straight or curved?

figure the really straight lines are made to appear curved, and in the Zollner illusion the parallel lines seem to diverge. Several explanations have been proposed for this type of illusion, none of which is entirely satisfactory. The theory that the *eye movements* of the observer are led astray by the oblique lines has some experimental support. The generalization that *small angles tend to be overestimated* applies obviously to the Poggendorf figure and more subtly to the other two. These illusions have important bearings upon problems of design. The architect, for example, must take care that oblique lines do not

modify each other so as to give an unfortunate or undesired effect.

Some other illusions are due to *the assumption of perspective* in a plane figure. Thus, in Fig. 75, the posts look successively taller, although they are really of the same height, because the other lines suggest that some are farther away than others. By habit we are accustomed to see objects of the same

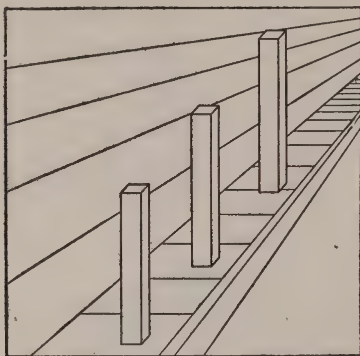


FIG. 75. The Perspective Illusion.

The upright posts are really of the same height, but they look successively larger because the other lines suggest that the third post is farther from the observer.

real size appear smaller as they become more distant. When this habit is deceived, as in the figure, an illusion results.

Illusions are not particularly important items in the study of the perception of form. The vast number of correct form perceptions that we make is more significant. Illusions, however, are not "exceptions" to the laws of perception, but illustrate the operation of these principles under unusual circumstances. Configuration, contrast, and perspective are useful aids to normal perceiving, as well as being the causes of illusions.

VISUAL SPACE

Persons see objects not only as possessing quality, intensity, and form, but also as having *depth* and as being at some *distance* from the observer. The visual world is three-dimensional,

and some account must be given of the ways in which the perception of space is achieved. The most accurate estimates of distance and depth necessitate the coordination of the two eyes, but some indications of space may be observed by one eye.

Monocular Perceptions of Space. The ability to perceive distance and depth with one eye is undoubtedly acquired by learning. The perception of the third dimension is based pri-

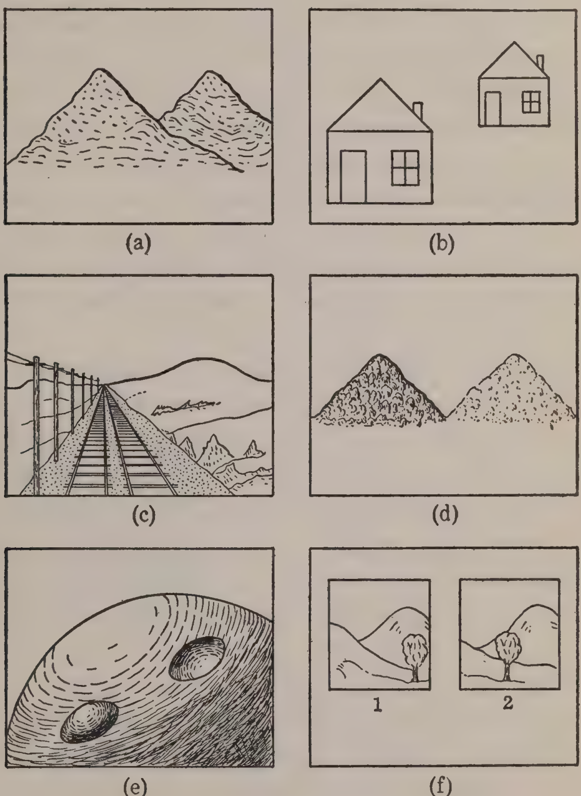


FIG. 76. Monocular Indications of Distance.

(a) Interposition. Which hill is nearer? (b) Relative size. Which house is nearer? (c) Linear perspective. (d) Aerial perspective, or relative clearness. Which hill appears more distant? (e) Light and shade. Which is an elevation and which is a depression? (f) Relative motion. Two views from the window of a moving train. What clue shows that the tree is nearer than the mountain on the right?

marily on movement and touch, and vision is only an indirect cue to distance and depth. In time, certain visual characteristics whereby nearer objects usually differ from those more distant are learned, and these serve as secondary cues to the perception of space.

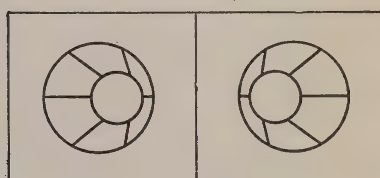
The most elementary indication of distance seen with the single eye is *interposition* (Fig. 76). An object that hides part of another object is taken to be nearer. *Relative size* is also useful in the case of familiar objects, since a man is assumed to be farther away if he appears smaller on the retina. With unfamiliar objects, size alone is not a reliable indicator of distance, since an object may be taken to be smaller and nearer than it really is, or vice versa. Closely allied to relative size is *linear perspective*. Figures of the same width appear to become narrower as they recede into the distance, and reach a "vanishing point" of insignificant width. Linear perspective is the most frequently used means for representing distance and depth in a plane picture.

Another factor in distance perception is *clearness*, or "aerial perspective." Near objects are seen in more detail, while those at a distance are less clear, largely because of haze in the atmosphere. In clear air this factor can be most misleading. *Light and shade* are especially useful in discriminating a protuberance from a depression, provided one knows or assumes the direction from which the light is coming.

Relative motion is another valuable clue to distance. This phenomenon can be seen when the head is moved from side to side, or when one rides in a vehicle. With a given amount of linear movement of the eye, near objects change their angle of view more rapidly than do distant objects. While riding in a train the near objects move past the eye rapidly and seem to be moving in an opposite direction from that of the train, whereas a distant mountain seems to pass along much more slowly and appears to be moving in the same direction as the train. Relative motion is a very delicate indicator of distance, since a small movement of the eye produces an appreciable change in the apparent positions of near and far objects.

Binocular Space. The perceptions of space that require the use of both eyes are more precise than those that can be obtained by one eye alone. Binocular space perception depends upon the fact that the two eyes have slightly different views of an object, and therefore the images of the right and left retinas differ. If one views a scene from a window and examines the two images by alternately closing each eye, the differences in the views framed by the window are quite noticeable. The different patterns of impulses from the two eyes are integrated in the brain and are interpreted in terms of distance and depth. The laws of binocular vision are similar to those of "relative motion" that have been described. In perceiving depth by relative motion one eye occupies two positions successively, while in binocular perception the two eyes occupy two positions simultaneously.

Binocular vision is illustrated by means of the *stereoscope*, an instrument that permits the presentation of two pictures in proper space relationship, one to each eye. Drawings may be made of objects as seen from the "right eye" and "left eye"



(a) (b)

FIG. 77. Binocular Perception of Depth.

(a) A stereoscope in use. This precision type of stereoscope is used for testing the convergence and fusion of the eyes. (b) A stereoscope slide of a truncated cone. The right and left eye views differ; and when viewed in a stereoscope, the small end appears nearer to the observer.

points of view. For example, a simple truncated cone whose small end is toward the observer yields the two views shown in Fig. 77. The right eye sees more of the right side and the left eye sees more of the left side. If these views are placed in a stereoscope, the cone is seen in three dimensions, "standing

out" toward the observer. Stereoscopic photographs are taken with two cameras whose positions correspond to those of the eyes.

The question as to whether the binocular perception of depth is a primary and native sensory attribute like redness or brightness, or whether it is dependent upon learning, has not been solved conclusively. The binocular perception of depth is present in children at the age of three years, and improves somewhat with increasing age. It has not been demonstrated with two-year-olds, but perhaps only because such young children cannot understand the instructions for the experiment. Clinical studies of persons who have acquired vision for the first time at a mature age, as by the removal of a cataract, indicate that they sometimes see two plane images, one for each eye, and that fused binocular vision is acquired only after practice. A large number of people do not have stereoscopic vision, usually because of poor acuity in one eye or because of muscular malfunctioning that hinders the coordination of the eyes. In such cases the individual often uses one eye predominantly and ignores the discordant image from the other. The resulting disuse of one eye may cause it to become almost blind, often without the knowledge of the individual. Some cases of this sort can be remedied by corrective training that compels the use of the neglected eye and the coordination of binocular functions. The bulk of the available evidence somewhat favors the hypothesis that the binocular perception of depth is learned by experience.

The Perception of Movement. A moving object occupies different positions with respect to its surroundings in successive moments of time. The perception of motion was formerly thought to present no problem, since a moving object casts a continuously moving image on the retina. If an object moves too rapidly it is seen as a blur, because retinal lag causes the images to overlap. A very small and very rapidly moving stimulus, such as the spoke of a bicycle wheel, may be quite invisible since it does not stimulate any part of the retina sufficiently to cause an adequate response.

The introduction of the motion picture raised a new problem in the perception of movement. Motion pictures are a succession of still pictures presented at a rate of 16 or 24 per second. Continuous movement, therefore, does not reach the eye from the cinema screen, but only a series of rapidly changing poses. Nevertheless, properly made motion pictures are perceived in continuous movement, not as a set of jerky postures. The speed at which pictures are made and shown does not permit the portrayal of a movement in imperceptibly small steps. Fig. 78 is traced from eight consecutive "frames" of a motion picture film that shows a man raising his arm quickly. The differences between the successive postures are very great, but the resulting picture shows a smooth rapid upward movement.

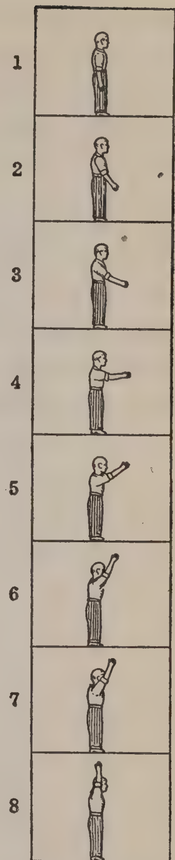


FIG. 78. Apparent Movement in Motion Pictures.

The figures show the arm angles appearing on eight successive frames of an actual motion picture film. When viewed on the screen, the movement appears as a uniform upward sweep of the arm. The entire movement takes only one-half of a second.

The perception of movement from a stimulus of successive still pictures has been variously called *apparent movement*, the *phi phenomenon*, or the *cinema illusion*. The effect can be simplified greatly for laboratory study. Two round lamps are placed behind a translucent screen and lighted in rapid succession. By such means the influence of the duration and intensity of each stimulus, the time interval between stimuli, and the distance between the objects can be experimented upon. When these three conditions are at their best the disk of light seems to travel from one lamp to the other, being clearly visible in the space where it does not exist physically. The distance between the stimuli and the time interval between their appearances are interrelated. If the apparent movement is destroyed

by altering the distance, it can be restored, within certain limits, by altering the time interval to compensate for the change in distance.

No thoroughly satisfactory explanation of apparent movement has been devised. It is certain that it does *not* depend upon the eye movements of the observer. Most theories recognize that apparent movement is an illustration of the general tendency to perceive wholes or configurations in everything that one sees. In trying to combine the rapidly successive images into one perceptual "whole," the visual-cortical mechanism creates the sense of movement between the actually stimulated points.

Chapter X

AUDITORY EXPERIENCE

Hearing is the experience resulting from the action of a sound wave on the receptor mechanisms of the ear. The sound wave itself is generated by a vibrating body, and is carried to the ear by molecular motions of a transmitting medium. The psychology of hearing therefore includes a discussion of three topics, namely: the vibratory action of sounding bodies and of sound media; the varieties of sound experiences that result; and the nature of the hearing mechanism of the ear and the nervous system.

Sounding Bodies and Sound Waves

Vibrating Bodies. When an elastic body, such as a stretched string or a column of air, is energized, it undergoes a vibratory motion. This movement may be felt if a stretched string that is emitting a sound is touched lightly with the finger. Vibratory motion is either *periodic* or *nonperiodic*, that is, regular or irregular. Periodic motion is also known as *harmonic* or *pendular motion*, the latter name being given to it because a swinging pendulum is a well-known instance of periodicity of movement, as shown by Fig. 79.

Vibratory motion is also *simple* or *complex*. In simple motion, the body vibrates only in its totality. The ordinary pendulum has a motion that is both simple and periodic, and is very nearly a *simple harmonic motion*. The vibrations of tuning forks also approximate such a motion closely. Most elastic bodies, however, and all musical instruments vibrate as a whole and also in fractional parts, or segments, at the same

time (Fig. 80). These fractional vibrations or *partials* are related in simple numerical ratios, such as 2, 3, 4, 5, etc., to 1. That is, the body vibrates as a whole, in halves, thirds, fourths,

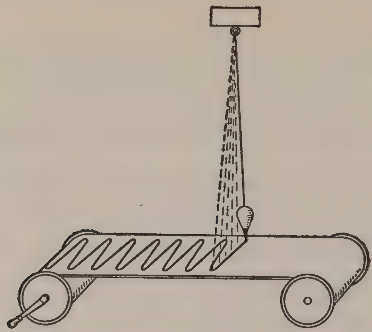


FIG. 79. Simple Harmonic Motion of a Pendulum.

The pendulum swings from a fixed point, moving back and forth across the paper. As the paper moves from right to left, a harmonic curve is traced on its surface. (From D. C. Miller, *The Science of Musical Sounds,* by permission of The Macmillan Company, publishers.)

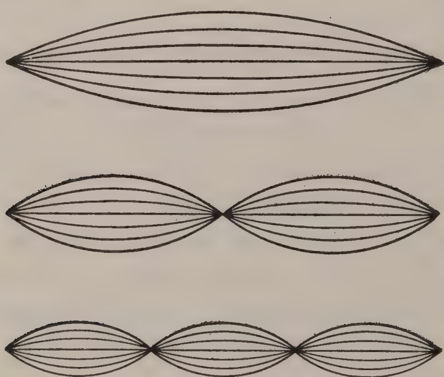


FIG. 80. Characteristic Vibrations of a Stretched String.

A string vibrates in its total length, in halves, in thirds, etc. The vibrations of the total string give the fundamental pitch; the halves and thirds produce the first and second overtones, respectively. A string vibrates in all of these ways at once, and has a very complex vibration.

fifths, and so on. Each of these separate vibrations is a simple harmonic motion, but when they are combined the resulting motion of the body may be very complex.

Every simple harmonic vibration has its *frequency*, which is the number of complete vibrations executed per second. The vibration of a body as a whole is at its *fundamental* frequency rate, while the partial vibrations are at frequencies that are multiples of the fundamental. If the fundamental vibration is at the rate of 100 per second, then the partials have vibration rates of 200, 300, 400, 500, and so forth. The fundamental vibration frequency of a sounding string or wire, for example, depends on its length, thickness, and tension. The frequency is inversely proportional to the length, inversely proportional to the square root of the thickness, and directly proportional to the square root of the tension. In general, this means that shorter, thinner, and more tense strings will have higher vibration frequencies, while longer, thicker, and less tense strings will yield lower frequencies.

Every vibrating body moves with a certain *amplitude*. The amplitude is the extent of the to-and-fro movement, the distance covered by the vibrating body from the position of rest to its maximum deviation. The amplitude with which a body vibrates depends upon the energy with which it is put in motion, and in turn determines the energy of the impulse that is given to the transmitting medium. After a vibrating body has been energized by one impact it gradually comes to rest. During this period the amplitude of vibration decreases to zero, but its frequency of vibration remains the same as long as it vibrates at all.

Sound Waves. A body undergoing vibratory motion transmits its motion to a surrounding elastic medium. This movement consists of a succession of compressions and rarefactions of the molecules of the transmitting medium, which are known as waves or cycles. Air particles set in motion by a vibrating body oscillate back and forth like the bob of a pendulum, but in a straight line from the source of sound (Fig. 81). In this way, the vibrations of the body are conveyed through the medium to a distant point. Such molecular movement can occur not only in air, but also in a solid or liquid substance. The air

is, however, the most common medium for sound communication. In air sound travels at a rate of about 1,120 feet per second, or about one mile in five seconds. In water its speed is about one mile per second, and in iron or steel about three miles per second. The speed of sound is independent of its frequency and amplitude, and depends only on the elasticity and density of the transmitting medium.

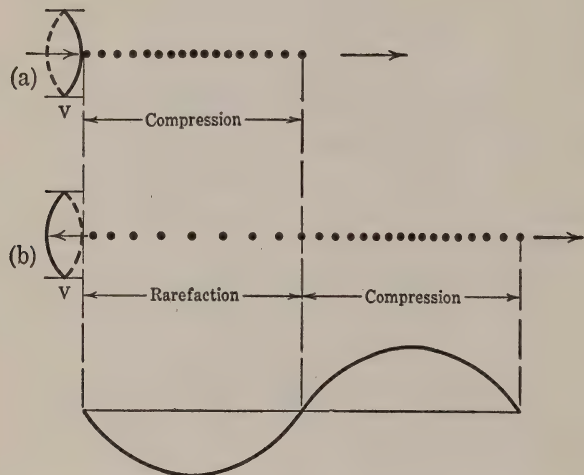


Fig. 81. Motions of Air Particles in Transmitting Sound.

In (a) the diaphragm or string *v* vibrates forward and pushes the air molecules ahead of it, resulting in a compression. In (b) the vibrating body *v* moves backward, causing a rarefaction. The first compression continues to move outward. The wave diagram below represents the rarefaction and compression.

Sound waves have *frequency*, *amplitude*, and *form or pattern*, corresponding to the motion of the vibrating body.

The *frequency* of a sound wave is the number of times that the wave pattern or cycle repeats itself per second, and is the same as the frequency of the sounding body. As a wave is propagated in a medium, its *wavelength* is the distance occupied by one whole cycle, a compression and a rarefaction, each of which occupies one-half wavelength. Wavelength is inversely proportional to frequency. In air, a wave of 400 cycles per second frequency has a wavelength of 2.8 feet or about 33½

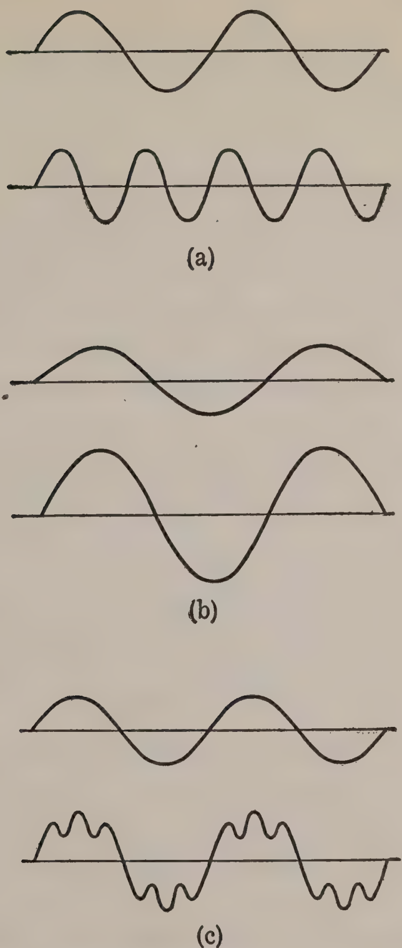


FIG. 82. Frequency, Amplitude and Form of Waves.

(a) Two waves of different frequency, but of the same amplitude and form. (b) Two waves of different amplitude, but of the same frequency and form. (c) Two waves of different form, but of the same frequency and amplitude. The more complex wave is made up of a fundamental and several partial vibrations.

inches, and a wave of 1,000 cycles has a wavelength of 1.12 feet or about 13½ inches. As sound waves are represented graphically, the frequency is proportional to the number of cycles in a given length, and the wavelength is the length of a complete cycle, as shown in Figs. 81 and 82.

The *amplitude* of a sound wave is the distance the vibrating air (or other) molecule travels before rebounding. This distance is very small, being about one ten-thousandth of an inch for a rather loud sound. When represented graphically, the amplitude is the distance from the middle reference line to the crest or trough of the wave form (Fig. 82). Wave amplitude is determined by the energy with which the sounding body sets the medium in motion; the stronger the energy, the greater the amplitude.

The *form* of the wave (Fig. 82) is determined by its composition, that is, by the component frequencies that make it up. A simple harmonic vibration yields a wave of simple form. If partial vibrations are superimposed the wave becomes more complex in form or pattern. A single wave may become almost incredibly complex, as when it conveys from the vibrating diaphragm of the radio loud-speaker a reasonably faithful representation of an entire symphony orchestra.

The Sound Experiences

Experiences of hearing result when sound waves strike the intact auditory mechanism of the ear and nervous system. Sound experiences are broadly classed as *noises* or *tones*. If they are tones, they possess the major properties of *pitch*, *loudness*, and *timbre*, and the minor properties, not agreed upon by all scientists, of volume, density, brightness, and vocality.

Pitch. The pitch of a sound is primarily a response to its frequency, although the other physical variables have some effect upon it. Sound waves below and above certain frequencies do not produce an auditory experience because of the limitations of the ear. The range for audible frequencies is from

about 20 to 20,000 c.p.s. (cycles per second). A periodic vibration within this range is experienced as being of a certain pitch. Pitch is the property of a sound that is referred to in popular speech by the terms high and low, or higher and lower. Low frequencies give low pitches, and high frequencies give high pitches.

Although frequencies of sound waves vary continuously, the ear is not sensitive enough to hear each frequency as a different pitch. Thus a small change in frequency can occur without there being a change in the conscious experience of pitch. In the middle of the tonal range, from 500 to 4,000 c.p.s., the frequency difference of two tones must be about 0.3 of one per cent to produce a just-perceptible difference in pitch. Frequencies closer together than this have the same pitch value for the average ear. Very high frequencies are discriminated less well as to pitch, and very low frequencies are still harder to discriminate, frequency changes of from 3 to 5 per cent being necessary to cause a noticeable pitch difference for frequencies below 100 c.p.s. The total number of discriminable pitch steps in the audible frequency range has been estimated to be about 1,375. These figures are for the auditory abilities of the average person. Some gifted individuals can do much better, whereas "tone-deaf" persons often cannot detect pitch differences for frequency changes as great as 10 per cent. Anomalies also are found, as in the cases of persons who hear the same frequency as different pitches with each ear.

The intensity or amplitude of a sound wave also affects the pitch to a minor degree. If the frequency of a sound is kept constant while its intensity is changed, its pitch will be heard to change. For low frequencies, pitch is lowered with an increase in intensity; for high pitches it is raised when intensity is increased. This effect is greatest for pitches above 5,000 c.p.s. or below 300 c.p.s. Pitches in the middle range centering around 2,000 c.p.s. are changed very little with variations in intensity.

Loudness. Loudness is the property of an auditory experience that is described by the terms weak and strong. A sound may be so weak as not to be audible, or so strong that the resulting experience is one of pain rather than hearing. The former constitutes the threshold for loudness, the latter is the threshold of pain. Loudness is chiefly a function of wave amplitude, or of the effective pressure of the sound wave as it reaches the ear. A greater amplitude of the wave causes a louder sensation of hearing, and vice versa.

The range of pressures or amplitudes that can evoke various degrees of loudness of hearing is enormous. In the middle frequency range, a tiny force of less than .0001 dyne per square centimeter[1] reaching the ear can cause a faint auditory sensation, and a force of over 500 dynes per square centimeter causes an extremely loud sound, but not yet pain. The ratio of the least to the greatest pressure to which the ear is sensitive is thus over 1 to 5,000,000. Because of the inconveniently large range of these figures, auditory intensity is usually measured in a more convenient unit known as the *decibel.* The decibel is a comparative unit stating how many times more intense one sound is than another, expressed in logarithmic units. One decibel is 20 times the logarithm of the ratio of the two pressures. To measure absolute intensity, the lower threshold of hearing at 1,000 c.p.s. is taken as equal to 0 decibel. The following data indicate the meaning of the decibel scale:

Ratio of Physical Pressure	Decibel Units	Example
1	0	Threshold
10	20	Country garden
100	40	Quiet office
1,000	60	Busy street
10,000	80	Pneumatic drill
100,000	100	Boiler factory
1,000,000	120	Loud thunder
10,000,000	140	Pain

[1] One dyne is the force that will give a 1-gram mass an acceleration of 1 centimeter per second per second. It is thus a very small unit of force.

The ear is most sensitive to pitches in the middle frequency range, and is less sensitive to high or low pitches, as shown in Fig. 83. Therefore, to be heard, a tone of high or low pitch

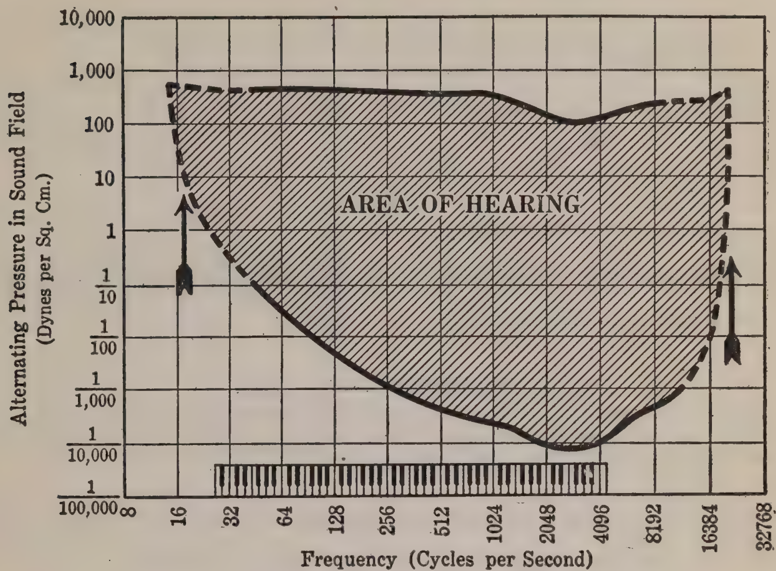


FIG. 83. The Limits of Audibility.

The normal ear can hear vibrations that vary in pitch from about 16 to about 20,000 vibrations per second. Vibrations having amplitudes or forces from about 1/10,000 dyne to about 500 dynes cause sensations of sound. The area of hearing includes the total pitch and amplitude ranges. (From H. B. Lemon and H. I. Schlesinger, *Sound, A Guide for Use with the Educational Sound Pictures, "Sound Waves and Their Sources," and "Fundamentals of Acoustics,"* University of Chicago Press.)

must be more intense than a tone in the middle region. A sound of 20 c.p.s. or of 20,000 c.p.s. calls for about 100,000 times the intensity of a sound of 3,000 c.p.s. in order to reach the threshold of audibility. Also, when tones of low, middle, and high pitch are sounded with equal physical intensity, the tone of middle pitch will seem louder than either the very low- or the very high-pitched sound. A tone of 2,200 c.p.s. is about eight times as loud as one of 64 c.p.s. when both strike the ear with equal force. The difference threshold for intensity, the varia-

tion in intensity that can just be noticed as a change in loudness, is likewise superior for the middle region of pitch. For a tone of about 62 c.p.s. the number of just-noticeable gradua-

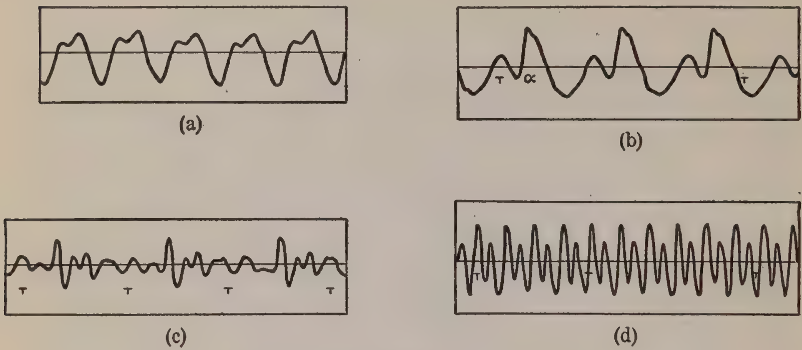


FIG. 84. Complex Sound Waves.

(a) A violin tone. (b) A sound from an organ pipe. (c) A bass voice. (d) A soprano voice. (From D. C. Miller, *The Science of Musical Sounds,* by permission of The Macmillan Company, publishers.)

tions in loudness between the threshold for sound and the limit of pain is 34; for 1,000 c.p.s., 374 degrees of loudness may be detected; but for 16,000 c.p.s., only 16.

Timbre. Different sound sources produce tones of different timbre, and hence timbre may be defined as that characteristic of a tone by which we recognize the source of a sound, whether it is a tone from a violin, horn, soprano voice, tenor voice, and so on. A large vocabulary of adjectives is used to describe timbre. When tones are described as rough or smooth, hollow or full, thin or rich, etc., the quality of timbre is being designated.

The timbre of a tone is determined by its form or pattern, that is, by its complexity (Fig. 84). As has already been indicated, most, if not all, natural sounds are compound sounds, that is, composed of a number of frequencies. The lowest frequency, caused by the sounding body vibrating as a whole, is the *fundamental* and determines the predominant pitch of the tone. The partial vibrations give the *overtones* or harmonic frequencies. The number and relative intensities of the over-

tones that are present determine the timbre of the sound experience. The elimination of all higher frequencies or overtones from a violin tone, which may be done by means of electrical filter circuits, makes the tone sound like that of a tuning fork. The tonal quality of a musical instrument can be reproduced synthetically by combining several pure tones of the correct frequencies and intensities. This is done by the "electric organ." The timbre of a tone is further affected by its pitch, intensity, and duration, since these produce changes in its harmonics. High- and low-pitched tones from the same musical instrument or voice have different timbres, and so does the same pitch produced at different intensities. No performer can sustain exactly the same timbre of tone for any length of time.

The law of tonal timbre was first formulated by Ohm in 1843, and is known as Ohm's Law of Acoustics. He demonstrated that the simplest kind of sound experience is that of

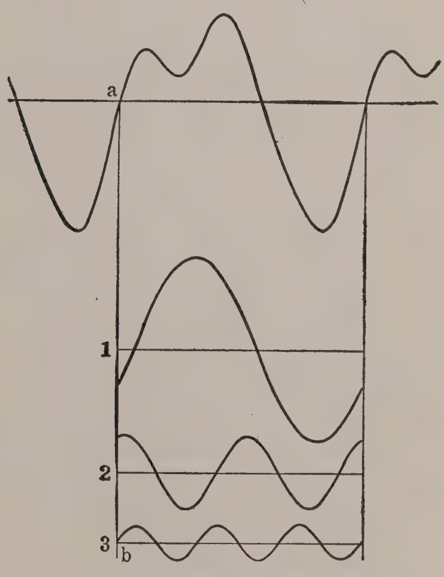


FIG. 85. Analysis of a Violin Tone.

The violin tone of Fig. 84a is analyzed into the fundamental (1) and the first and second overtones (2 and 3). (From D. C. Miller, *The Science of Musical Sounds,* by permission of The Macmillan Company, publishers.)

simple harmonic motion, and that all musical tones, with their variety of musical quality, arise from particular combinations of simple tones. Fourier showed later that all complex periodic motions can be analyzed into a series of simple harmonic motions, the frequency of each being a multiple of that of the complex motion. He also developed mathematical methods for analyzing the component harmonics of a complex tone. Fig. 85 shows a partial analysis of a violin tone according to Fourier's method. The fundamental has the same wavelength as the complex tone, while the first and second overtones have frequencies two and three times that of the fundamental. If the three harmonics are recombined they will produce the complex wave shown.

Minor Qualities of Sound. In addition to the three indisputable qualities of pitch, loudness, and timbre, several other dimensional qualities of sound have been proposed by various experimenters.

The *volume* of a tone is described as its spatial property, its bigness or area. Volume seems to correlate with pitch, loudness, and timbre. Low-pitched tones seem broad, heavy, extensive, big, and occupy much space, whereas high pitches are light, narrow, small, and occupy a point in space. Loud tones have greater volume than weak tones. Timbre, too, seems to play a part in volume, since a rich, full tone with many overtones seems more massive than does a thin, simple tone. It has been shown experimentally that observers can make two tones of different pitch seem to have equal volume by increasing the loudness of the higher pitched tone. The experience of tonal volume is reported quite consistently by almost all people, but it is doubtful whether it is an intrinsic property of hearing, or whether it is based on the association that larger sounding bodies usually produce tones that are deeper, louder, and richer in overtones.

The *density* of a tone relates to whether it is hard, compact,

and tight, or loose and diffused. High pitches are judged to be more dense than low pitches, and louder sounds more dense than faint ones. Density is not the same as volume, for the loudness variable is the same for both, whereas higher pitch decreases volume but increases density.

Variation in *brightness* of tones has been observed in comparing the sounds produced by musical instruments. Some tones so produced are bright and flashing, while others are dull or lifeless. Experimental studies have identified brightness with a certain aspect of timbre. In a bright tone high-frequency partials or overtones are present in considerable strength, while a dull tone lacks these upper overtones.

Certain pitches, even when pure and simple harmonic waves, seem to "say" certain vowels. This quality is called the *vocality* of the tone. The approximate frequencies that seem to have vocality are as follows:

Pitch Frequency	Vowel
325 c.p.s.	o͞o, as boo
460 c.p.s.	ō, as bone
900 c.p.s.	ä, as bah
1,800 c.p.s.	ă, as bat
2,500 c.p.s.	ā, as bait
3,000 c.p.s.	ē, as beat

Vocality is undoubtedly an associative quality. The normal voice in ordinary speech produces the various vowels each with a characteristic predominant pitch. The vowels become associated with the pitches at which they are spoken.

Noise and Tone. In common usage, a noise is an undesired sound. In this sense the finest music may be a noise if it blares from a neighbor's radio when one is trying to concentrate on a difficult problem. In a more limited sense, as employed in the psychological and acoustic meaning, a noise is a sound that does not result in a clear sensation of pitch. A sound may be a noise rather than a tone for a considerable number of rea-

sons—because it is nonperiodic, too low or too high in frequency, too complex, too short in duration, or too irregularly variable in loudness.

The commonest source of noise is irregular, nonperiodic vibration. If the sound waves do not repeat their pattern at regular time intervals, noise is the resulting experience (Fig. 86). A noise can have some trace of pitch, however. A "sharp"

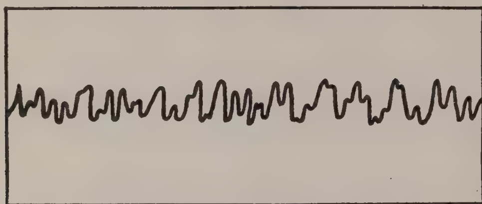


FIG. 86. Noise.

This irregular or nonperiodic vibration has no definite pitch, and is heard as a noise.

noise caused by striking an iron pipe has a higher pitch component than a "dull" noise set up by a blow on a wooden floor. Probably there is no exact boundary between tone and noise, but each merges gradually into the other according to the degree of irregular complexity involved.

Very low frequencies of sound are usually heard as noises. In experiments on the perceptions of sounds of frequencies of 5, 10, 15, 20, 25, 30, 40, and 60 c.p.s., it was found that four auditory phenomena were reported, namely, noise, intermittence, thrusting effect, and tone. For 5 c.p.s., some observers heard nothing, others heard a pumping noise which they described as "choo-choo," "chug-chug," and "high-pitched beat." For 10 c.p.s., the pumping noise was louder and faster in rate, consisting of a faint flutter, or intermittent pulses that seemed to emerge from the pumping noise. At 15 c.p.s. the intermittence became prominent, and a thrusting effect like that of a loose bearing or piston was also described. At 20 c.p.s. a suggestion of tone appeared; this became quite definite for most

observers at 25 c.p.s. and even more prominent at 40 c.p.s. At the other end of the range of audible frequencies, sounds of about 15,000 c.p.s. are usually reported as "a hissing noise." These results indicate that as the frequency becomes too low or too high, tones merge continuously into noise, with some transitional stages observable.

It is also possible for a noise to be a sound of too short duration to permit a sense of pitch to develop. Experimental results with tones from tuning forks show that the duration of a pure tone necessary for hearing a definite pitch is about from 1/25 to 1/10 of a second, depending on the frequency and intensity of the stimulus. The higher the frequency, or the greater the intensity, the shorter is the required duration for the perception of tone.

Because of individual differences in auditory sensitivity, what is a tone to one person may be a noise to another. For most people, the very lowest and highest keys on the piano are much more noises than tones because they do not evoke a definite pitch experience. On the other hand, a few individuals with great musical sensitivity can identify and name the component pitches that are present in a complex sound that is a noise to the ordinary ear.

Beat Notes and Combination Tones. If two tones having a small frequency difference are sounded together a single pulsating or beating tone is heard. The beats are periodic fluctuations in loudness, and occur at a rate equal to the difference between the frequencies of the tones. Thus tones of 400 c.p.s. and 402 c.p.s. give a beat note of two beats per second. Beats are due to the interaction of the two sound waves as they alternately reinforce and interfere with each other. Beats have a ragged and unpleasant sound, and their presence explains the annoying effect produced by two tones that are not far apart in frequency, such as those of adjacent keys on the piano.

Two simultaneously sounding tones of greater frequency difference give rise to a third tone whose frequency is equal

to their difference. This is called the *difference tone*. For example, if two forks of 2,800 c.p.s. and 3,200 c.p.s. are struck together, the difference tone of 400 c.p.s is easily audible. Orchestras must take difference tones into account, for they occur whenever two instruments play different frequencies together, and may add to the composition or detract from it. A *summation tone* equal in frequency to the sum of the frequencies of two sounded pitches also occurs, but it is small in amplitude and is not easily heard under ordinary conditions.

Masking. It is common experience that a louder tone may mask or "drown out" a weaker one, so that the latter may become inaudible. For example, conversation may become impossible while a noisy train rushes past. Experimental studies have uncovered some interesting facts about the masking of pure tones. First, a loud tone masks frequencies near and above its own more effectively than it masks lower frequencies. Thus a very loud tone of 1,200 c.p.s. renders almost inaudible all higher frequencies, but has practically no masking effect on frequencies below 800 c.p.s. Second, a tone has less masking effect upon its harmonics than upon other frequencies. The 1,200 c.p.s. pitch has relatively less masking effect on exactly 2,400 c.p.s. and 3,600 c.p.s., although it smothers all frequencies between these two. This fact has important bearing on the ability of faint overtones to enrich the timbre of a tone.

Sound as Music[2]

The Musical Scales. The most basic fact of sound in relation to music is the phenomenon of *octave quality*. If we begin with any pitch and ascend or descend from it by discrete steps, another tone is reached that gives the effect of being a repetition of the first tone. This tone always has a frequency *half* or *twice* that of the first tone. It is called the *octave* because musical notation divides the interval between multiple frequencies

[2] This section may be omitted without destroying the continuity of the chapter, if it is desired to do so because of lack of interest or training in music.

into seven steps, so that the repeating tone is always the eighth (octave) one, counting the first tone. The entire range of heard frequencies is divided into a recurrent series of eight-toned groups known as *scales*. Our diatonic scale is made up of a series of tones that have a simple ratio to the tonic, or first tone of the scale, and also to each other, as follows:

	c	d	e	f	g	a	b	c^1
(Ratio to tonic)	1	9/8	5/4	4/3	3/2	5/3	15/8	2
(Ratio between tones)	9/8	10/9	16/15	9/8	10/9	9/8	16/15	

With these ratios the frequency of any tone in the scale can be computed from the frequency of the tonic. Thus, if the tonic is 200 c.p.s., the scale in frequencies is 200, 225, 250, 266.66, 300, 333.32, 375, 400. Musically, the steps between the tonic and the other tones of the scale are called, respectively, the unison, major second, major third, perfect fourth, perfect fifth, major sixth, major seventh, and octave. Each one of these is called an *interval*. The interval between any two consecutive tones is either a major or minor second, which means a whole step or a half step.

Tones in Succession: Melody. When a succession of tones gives the impression of belonging together, of forming a continuity of motion, the succession is called a melody. The smallest tonal unit that can produce the effect of such onward progression is an interval. Psychologically two tones can form a melody if they are felt to belong together and to come to a close. Some of the intervals of the scale give such an effect, while others call for a third tone to reach a point of rest. An interval is therefore static or dynamic. It is static if it is complete in itself, and dynamic if it needs a third tone to complete the succession. The static intervals of the scale are the unison (1:1), the octave (1:2), and the perfect fourth (3:4). The major second (8:9), the major third (4:5), the perfect fifth (2:3), and the major seventh (8:15) are dynamic. The major sixth (3:5) is uncertain. Now it is noticeable that the static intervals have for their second tone the number 2 or a pure

power of 2, such as 4, 8, 16, etc., while in the dynamic intervals the first tone is 2 or a pure power of 2, and each of these intervals demands a return to the first tone for its completion. This dominance of the number 2, or one of its pure powers, in a tonal succession is known as the law of the *tonic*, and plays an important rôle in musical melody. It is also known as the law of *tonality*.

Musically a tonal succession is a melody only when it contains at least two balanced rhythmical phrases and comes to a complete close. The first six measures of "America" form such a simple musical sentence. The third and fourth measures balance the first and second, and the fifth and sixth complete the sentence. Each tone in the melodic line pulls toward its neighboring tone, and all pull toward one final tone, the tonic. And the tonic is invariably 2 or some pure power of 2. A musical melody is therefore a tonal succession that gives the effect, or experience, of a group of mutually related tones moving about a single tone, the tonic, and coming to a close on the tonic. Unless a series of tones establishes in the hearer such a central tendency, a tonality effect, the series will be called not a melody, but a succession of disjointed sounds. A melody is therefore not something given objectively, but something formed subjectively. It is a series of muscular tensions and relaxations, each tone as it occurs setting up an expectation for its successor, and an anticipation of a rounded-out, organized, completed whole. Gurney has given the best account of the subjective melodic phenomenon in his definition of a melody as an "ideal motion." Like a verbal sentence, a melody is a musical idea, a melodic form that evolves in time, a continuous advance toward a finality. Each tone and each interval are related to the whole which is as yet in the making. It is a potential whole in the process of formation.

The basic factor making for the melodic relativity of tones is pitch proximity: the closer that several tones are to each other in pitch, the greater is their effect of belonging-together-

ness. In a count of the frequency with which intervals of different size occur in one hundred and sixty songs by several great composers, Ortmann found a marked predominance of small intervals over wide ones. He counted approximately 23,000 intervals and found that in 97½ per cent of the songs unisons or seconds were first in frequency, and thirds in the other 2½ per cent.

Simultaneous Tones: Consonance or Dissonance. The effect of belonging-togetherness is also produced by some of the intervals of the musical scale when sounded together, while others seem to clash and pull apart. The results of numerous experimental investigations indicate considerable agreement as to which are the consonant and which the dissonant intervals. The octave is invariably placed as having the highest consonance; then come, in order, the perfect fifth, perfect fourth, minor sixth, major sixth, major third, minor third. The minor seventh, major seventh, major second, and minor second are the dissonances.

The outstanding theories concerning the basis of the consonance-dissonance phenomenon are those of Helmholtz and Stumpf. According to Helmholtz, consonances are the result of the complete, or almost complete, absence of beats of the upper partials, the effect being, therefore, smooth. In dissonances the mass of sound is broken up into pulses, and the joint effect of the two musical tones is rough. The absence or presence of noticeable beats depends upon the pitch ratio of the two tones. The octave is the best consonance because the partials of its constituent tones coincide and therefore no beats are present. Stumpf's criterion for consonance is fusion, which he defines as the impression of singleness produced by two simultaneous tones. The degree of consonance of an interval is the degree of singleness of impression produced by the two tones. Singleness of impression does not mean that the two tones are heard as one tone. It is the experience that is unitary, not the stimulus. What happens in fusion is that the hearer is

aware of the presence of two tones, but he experiences them as a blend. As a single impression the experience is unanalyzable. With decrease of fusion the experience becomes increasingly more analyzable into several impressions. Degree of fusion is thus degree of consonance and dissonance.

Auditory Perception of Distance and Direction

Persons can locate the distance and direction of a sounding body. How do we do so, and with what accuracy? To answer the question we must bear in mind the nature of the phenomenon of hearing, namely, that a sound is the result of the stimulation of the auditory mechanism by an atmospheric wave generated by a vibrating body, and that this wave has amplitude, frequency, and form, giving rise to the experiences of pitch, loudness, and timbre. Now the amplitude, frequency, and wave form of a vibrating body itself remain constant, but changes occur in the wave as it travels through the air. This means that the direct stimulus for hearing is not the vibrating body itself, but the characteristics of the wave as it strikes the ear; and these characteristics of the wave change as the distance and direction between the sound source and the observer are changed. Hence the key to sound localization must lie in the changes produced by distance and direction upon the properties of the wave. The properties are the physical signs for distance and direction.

The Physical Signs for Distance. It is a well-known principle in physics that the amplitude of a wave propagated through the open air varies inversely with the square of the distance. In other words, the loudness of a sound decreases with an increase of the distance between an observer and the source of the sound. Hence the estimate of the distance of a sound is made, for one thing, in terms of its *loudness*, namely, that the louder the sound the closer it will be judged to be. When two sounding objects are equidistant from an observer and the two tones differ only in intensity, the louder of the two will, in most

cases, be judged to be closer. Experimental data show, however, that this does not hold for distances greater than 240 cm., probably because of the fact that a difference in the intensity of two tones decreases as the distance of the sounding objects increases. When two tones differ in intensity but are equidistant, there is a tendency to perceive the louder tone to be both louder and closer. When they have equal intensity but are at different distances, the nearer one is pronounced to be both nearer and louder. It seems then that there is an association between nearness and loudness.

It is also a well-established fact that *wave form* varies with distance, namely, that a tone becomes purer as its distance from an observer is increased. This happens because the higher partials, having weaker intensities, gradually become inaudible with increases in distance, bringing about a change in tonal quality. Data from experiments with two tones of the same pitch and intensity but differing in complexity, with the more complex tone placed at a distance of 15 feet and the less complex at 10 feet, show that there is a marked tendency to judge the more complex tone to be also nearer. When we hear a train whistle from a great distance the sound is hollow because of the absence of its higher overtones, but close by it is shrill owing to the prominence of the upper partials.

The effect of *pitch* on the perception of tonal distance is very uncertain. But since low tones have greater carrying power than high tones it is possible that lower tones are judged to come from greater distances than high tones.

Sound Localization. The judgment of the direction from which a sound comes—whether from the right, left, front, back, up, or down—has been the subject of many experiments. A simple experiment may be performed by blindfolding a subject, sounding a click a number of times in random order from each of the directions named, and requiring him to report the position from which each click seems to come. If a record is made of the results, it will be found that he judges the sounds from right or left correctly on every trial, but that sounds that

come from front, up, back, or down are usually confused, and are located little better than by chance guessing. It will be noted that front, up, back, and down lie in a plane equidistant from the two ears, the *median plane* of the body. The first finding of experiments on sound localization, then, is that the various directions that lie in the median plane are distinguished from one another very poorly. Evidently the sound must be nearer one ear than the other for its direction to be perceived.

In the horizontal plane of the body, defined by the directions front, right, back and left, a blindfolded subject can point to or otherwise indicate the direction of a sound with some accuracy. This ability is best for sounds just a little to the right or left of the median plane. The "rightness" or "leftness" of a sound is evident if it departs as much as three or four angular degrees from the median plane. Localization is poorest for sounds just a little front or back from the line of either ear.

Auditory localization by the use of two ears (*binaural* localization) depends on a number of differences that the sound wave has from one ear to the other, namely, intensity, complexity, time of initial stimulation, and phase. When a sound wave, led to each ear by an individual tube, stimulates both ears with equal intensity, the source is located as in the median plane. If the intensity is different in each ear, the sound is located toward the ear that receives the greater intensity. In real life, it is evident that a sound from the left reaches the left ear with greater loudness because the right ear is screened by the head. Furthermore, the left ear will receive the initial impulse sooner than the more distant right ear. The tonal complexity of the wave received by the nearer ear is greater than that received by the farther ear, because the screening by the head destroys certain higher overtones. Finally, there is the phase relation. Two sound waves are said to be "in phase" when the tips of the crests and the bottoms of the troughs occur at exactly the same time for both. If a sound is equidistant from the two ears it will reach each ear in the same phase; but if the wave has to travel farther to reach one ear, it will

be at a different phase upon its arrival. In all real situations, it is probable that the four cues—intensity, complexity, time, and phase—all contribute to localization. In general, noises and complex tones are easier to locate than sustained pure tones, since they give more cues. It is also easier to locate a low pitch than a high one. The difficulty of locating a cricket, which emits a high pitch, is an example of this.

Monaural sound localization, with one ear alone, is much more difficult and less accurate than binaural localization. Persons who are deaf or hard of hearing in one ear make poor localizations, and normal persons decrease in accuracy when one ear is plugged. Some localization can still be achieved by judgments of intensity and complexity, or by turning the head to try the direction of the sound.

The Hearing Mechanism and Its Operation

The parts of the ear which constitute the mechanism for hearing may be considered anatomically as divided into the outer ear, the middle ear, and the inner ear. The gross anatomy of these three divisions is represented in Fig. 87.

The Outer Ear. The visible portion of the outer ear is called the auricle or pinna, known popularly as the shell. The external meatus, or auditory canal, connects the pinna internally with the eardrum or tympanic membrane which forms the boundary between the outer ear and the middle ear. This canal is about an inch long and somewhat irregular in curvature. It is lined with thick skin and is protected against the entrance of foreign bodies by thick hairs that grow from the skin toward the entrance, and by a secretion of thick wax. The tympanic membrane consists of radial and circular fibers covered on the outside by a very thin skin and on the inside by a mucous membrane. It is about one centimeter in diameter and slightly conical in shape.

The Middle Ear. The middle ear is contained in an irregularly shaped cavity of the temporal bone. This cavity is filled with air, and has a ventilation shaft, the Eustachian tube,

leading to the throat by means of which the air is frequently renewed. This tube opens during the act of swallowing and permits adjustment of the air pressure within the middle ear in relation to that outside. Within the cavity of the middle ear is a chain of three tiny bones, the malleus (hammer), incus (anvil), and stapes (stirrup). These three bones are stretched across the cavity from the tympanic membrane to a small oval-

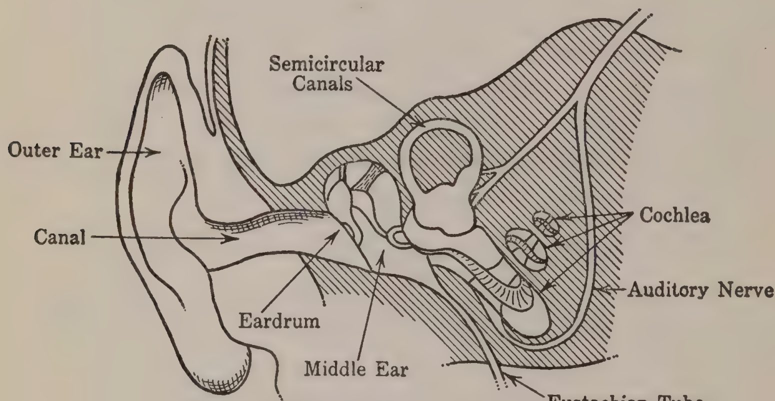


FIG. 87. The Ear.

shaped membrane, the oval window. The bones are held together by ligaments, and muscle tissue connected to them controls their tensions and also the tension of the eardrum. Vibrations set up at the drum are transmitted by these three bones to the inner ear which contains the sense receptors for hearing.

The Inner Ear. The inner ear is located in a bony labyrinth. It contains three divisions: the *vestibule* and the *semicircular canals* which are concerned with bodily equilibrium, and the *cochlea*, which is the structure concerned with hearing. In form, the cochlea looks like a small snail shell, being large at one end and small at the other, and coiling around for two and one-half turns. Within this structure is the cochlear canal which winds its way around inside the bony frame. The canal

is divided longitudinally into two almost equal parts by a floor, one half of which consists of a bony balcony projecting from the wall of the cochlea, and the other half of a movable structure called the *basilar membrane*. The two tubular portions thus formed are connected at the apex end of the spiral structure by a small opening, the helicotrema. They are filled with a liquid which vibrates when excited by the oscillations of the middle ear. The oval window, which receives the foot of the stirrup bone, transmits vibrations to the liquid in the upper part of the canal, through the helicotrema, to the lower tubular portion which ends at the round window. The round window, which is closed by a flexible membrane, functions to absorb excessive vibrations which are set up within the cochlear canal.

The basilar membrane carries the sense receptors of hearing. This membrane is made up of fine transverse fibers of different lengths. Upon the basilar membrane rest the "hair cells" of the *organ of Corti*, which are the actual sensory elements of hearing, since they connect directly with the many fibers of the auditory nerve. As the liquid substance within the cochlear canal causes the basilar membrane to move up and down, the hair cells likewise vibrate, stimulating the endings of the neurons of the auditory nerve.

The Hearing Process. The operation of the entire mechanism of hearing may now be described concisely. The external ear or pinna aids somewhat in gathering and focusing the sound waves, although the human external ear is probably very inefficient for this purpose. The air waves travel down the meatus, or canal, and impinge on the eardrum, setting it into vibratory motion. The movements of the drum are then communicated to the chain of bones of the middle ear, being converted into mechanical pushes and pulls. The movement of the bones sets the membrane of the oval window in vibration. This vibration sends pressure waves through the fluid of the cochlear canal, causing corresponding up and down movements of the basilar membrane. Movements of this membrane thus

stimulate the hair cells of the organ of Corti, and these stimulations cause waves of impulses to travel up the fibers of the auditory nerve to the hearing center of the brain.

Theories of Hearing

Numerous theories have been offered to explain how we can hear tones of different pitches and different intensities. All these theories are divisible into two groups: namely, *place* theories and *frequency* theories. The place theories account for pitch perception on the ground that different tones cause vibratory movements in different regions of the basilar membrane, exciting the specific auditory fibers that supply the particular region affected. The frequency theories hold that the basilar membrane responds alike to all frequencies, pitch differentiation occurring as a result of the transmission by the nerve fibers of impulses whose frequency corresponds to the frequency of the sound wave.

Place Theory. The best known of the place theories is the *resonance* theory, first proposed by Helmholtz, and since his day considerably modified. The basis of this theory is the principle of sympathetic vibration or resonance. A string of the piano can be set in vibration by resonance when the damper is lifted and a tone sounded whose pitch corresponds to that of the string. A resonator responds most intensely to the pitch that is closest to its own frequency. The resonance theory of pitch differentiation therefore assumes that the transverse fibers of the basilar membrane are a series of resonating strings tuned to different frequencies, so that a particular tone excites a particular portion of the membrane. The nerve fibers supplying this portion are thus stimulated and transmit impulses which result in the perception of a tone of that particular pitch. According to this theory, then, the correlate of pitch is the particular nerve fibers excited, analysis being made by the fibers of the basilar membrane. The perception of loudness is said by this theory to result from the frequency of impulses in the nerve response, the greater the number of impulses the louder the tone. The number of impulses is

determined either by the amplitude of the sound waves producing a greater amplitude of movement in the particular region of the basilar membrane involved, or by the greater number of nerve fibers excited, as the result of a wide spread of response on the basilar membrane. One difficulty with the resonance theory is that nerve impulse frequency has been found to be correlated also with sound frequency, whereas, in this theory, frequency of nerve impulse should be correlated only with sound intensity.

Frequency Theory. The best known of the frequency theories is the *telephone* theory, first suggested by Rutherford and more recently amplified by Boring. Frequency of nerve impulse, according to this theory, is directly correlated with the frequency of the sound wave, resulting in the perception of pitch. The basilar membrane plays a rôle like that of a telephone transmitter, relaying to the brain impulses similar in frequency and waveform to the sounds striking the ear. Unlike the "place" theory, analysis of the sound is said not to occur in the cochlea, but in the brain. The auditory nerve fibers are excited at the same frequency that actuates the basilar membrane. A wave of greater amplitude actuates a larger portion of the basilar membrane, and this in turn excites a greater number of nerve fibers, causing difference in loudness. The shortcoming of this theory is the assumption that the rate of response in the auditory nerve fibers may rise as high as 20,000 per second for the highest audible tones, whereas it has been demonstrated that the maximum frequency of nerve discharge is 1,000 per second.

The Volley Theory. A theory that attempts to reconcile the difficulties encountered by both the place and the frequency theories has been formulated recently by Wever and Bray as the *volley* theory of hearing. This hypothesis suggests a way in which a group of nerve fibers can cooperate to transmit a series of impulses at a frequency greater than any single fiber can attain. It is supposed that a number of neurons discharge at different rates and not in synchrony with the others, and yet all in synchrony with the stimulating frequency. Thus one

neuron may discharge at alternate compressions of the sound wave, another at every third peak, another at every fourth, and so on, as shown in Fig. 88. The entire "volley" thus can reproduce the frequency of the wave, although no one fiber can reach this frequency because of the time required for its refractory phase.

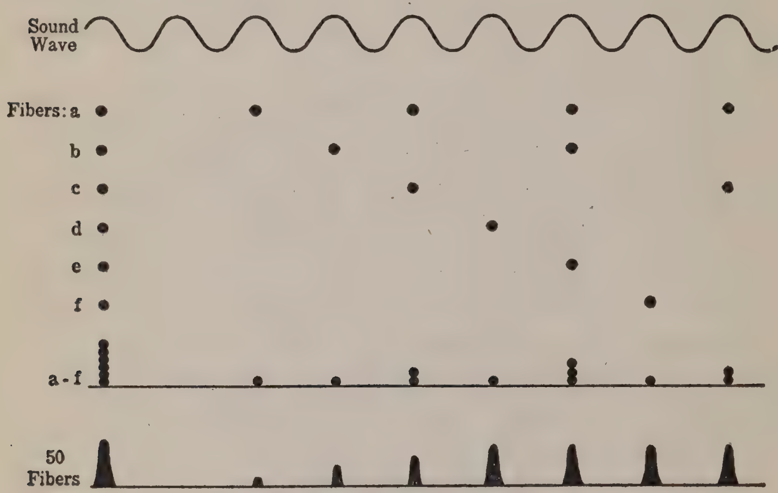


FIG. 88. The Volley Theory.

Each fiber responds at a frequency below that of the sound waves, but in strict synchronism with the sound waves. A number of fibers might give the effect shown at the bottom of the figure, representing faithfully the frequency of the sound. (E. G. Wever and C. W. Bray, *Psychol. Rev.*, 37:377, 1930.)

Loudness, according to the volley theory, is explained on the same basis as are all intensities of sensory or motor nerve discharge. It is due to the total number of nerve impulses reaching the brain per period of time. If the amplitude of the wave is greater, some of the slower neurons will be stimulated to double their rates of discharge. Also, additional fibers whose intensity thresholds are higher will join the volley when stimulated more strongly. Thus the total number of impulses will increase with intensity, but the net frequency will remain the same.

Chapter XI

OTHER MODES OF EXPERIENCE

The preceding two chapters have described the perceptual experiences brought about by the stimulation of the two most highly developed and specialized sense receptors of the human organism, the eye and the ear. This chapter is devoted to a study of the various experiences aroused by the several remaining sense organs. They include the specialized receptors for *taste* and *smell,* and the more general bodily or *somesthetic* senses. The somesthetic senses comprise all those not classed among the more specialized senses, including: (1) the *cutaneous* or skin senses; (2) the *kinesthetic* sense of the muscles, tendons, and joints; (3) the *labyrinthine* or equilibrium sense; and (4) the *organic* senses such as hunger, thirst, and sex.

Gustatory and Olfactory Experiences

Gustatory experiences (taste) and olfactory experiences (smell) are closely related. The qualities of both depend upon the chemical action of stimuli, and the same stimulus substance often serves to arouse perceptions of both taste and smell simultaneously. The experience popularly called the "taste" of food in the mouth is usually a blend of both taste and smell, and many experiences commonly described as "taste" are really of smell. When olfaction has been eliminated, many foods become "tasteless."

Taste Receptors, Stimuli, and Qualities. The receptors for taste, known as *taste buds*, are scattered over the tongue, the soft palate, and parts of the throat. The taste buds on the

tongue lie in papillae or small elevations surrounded by deep grooves in which the saliva collects. Fig. 89 shows a top view

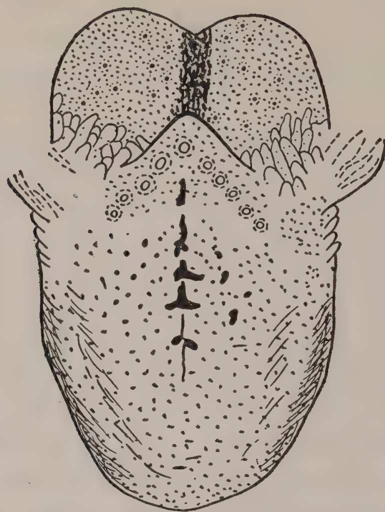


FIG. 89. Top View of the Human Tongue.

This surface view of the tongue shows three kinds of papillae, or small projections of tissue containing numerous taste bud receptors: (1) The cone-like structures surrounded by ring-shaped depressions situated in a V-shaped line across the back of the tongue. (2) The leaf-like formations situated along the edges toward the back of the tongue. (3) The small mushroom-shaped structures on the front and margins of the tongue.

FIG. 90. Cross Section of the Tongue.

This drawing of a cross section of a papilla of the tongue shows the deep grooves in which saliva with the taste substances collect. The taste bud receptors can be seen on the sides of these grooves, each with its nerve fiber connections.

of the human tongue and the papillae, and Fig. 90 shows a cross section of one papilla with the grooves and taste buds.

An adequate stimulus for taste is a chemical substance in solution; hence substances that are not soluble are tasteless. It is a function of saliva to reduce solid food substances to a solution. Experiments show that there are only four primary taste qualities: *sour, salty, sweet,* and *bitter*. It is probable that each taste bud detects only one of these qualities, but this has not been proved rigorously, since one papilla contains a number of taste buds close together and may be sensitive to more than one quality. When food is taken into the mouth a large number of widely distributed taste buds is stimulated simultaneously, so that a person may not know that there are particular regions of the tongue highly sensitive to specific taste qualities. But the tip of the tongue is most sensitive to sweet, the sides to sour, and the base to bitter; the saline quality is distributed quite generally over the entire upper surface.

Taste Mixtures. The four qualities of taste do not give a great variety of experiences, but the number is enlarged by mixtures and blends. Many substances stimulate more than one taste quality, and may be described as sour-bitter, sour-salty, and the like. Such is the case when a sour stimulus such as lemon juice is mixed with a sweet stimulus as in weak lemonade. The resulting experience is a sour-sweet *fusion*. In some fusions the elements are clearly distinguished, but in others the individual components may be hardly recognizable.

If one component of a mixture is much stronger than another, the weaker stimulus may be *suppressed*. Thus a little sugar added to a vinegar salad dressing may be entirely suppressed by the predominant sour taste. The perception of each component in a mixture will be weakened by the presence of the others. Such a mutual weakening is known as *compensation*, and is best observed in the mixture of rather weak solutions. Thus, sour, salt, and sweet may be mixed in solution without producing a new experience such as is found in complete fusion, but each ingredient is perceived as being weaker than when tasted in isolation.

Total experiences of food in the mouth include cutaneous

sensations as well as those of taste and smell. A good example of this is the experience of eating a strong onion or a red pepper. We get not only a taste quality and an odor quality, but a tactual quality as well, which we commonly describe as "burning," "hot," "prickling," and the like. This is due to the stimulation of pain receptors in the mouth. Other substances give patterns of stimulation involving pressure, warm, and cold sensations. Experiences usually called "taste" are therefore very complex patterns which have various gustatory, olfactory, and cutaneous components.

Taste Adaptation. Adaptation, or the weakening of a taste experience with continued stimulation, is rather slow and occurs only in response to long exposure of the receptors. A strong taste stimulus may partially or completely abolish one of the four primary taste stimuli, leaving the other three classes sensitive. This helps explain an apparent successive contrast which causes a sweet apple to taste very sour when candy has just been eaten. The apple has both sweet and sour taste components, and normally the sweet element is predominant, but the sour element may become dominant after the sweet receptors are "fatigued" as a result of the candy being eaten. Similarly, the apple may taste especially sweet after a piece of lemon has been eaten.

Another phenomenon of taste observable in everyday life is that gustatory sensitivity becomes less acute as age increases. This is quite noticeable in those individuals who require an abnormal amount of seasoning in their foods. Decreasing sensitivity with age is more pronounced in taste than in the other senses, largely because of a gradual atrophy of the taste receptors and the "gumming up" of the papillae with food particles. Loss of taste is further enhanced by the fact that the olfactory senses become less acute in old age.

Smell Receptors and Their Stimuli. The receptors for smell consist of a large number of *olfactory cells* secluded in the uppermost part of the nasal cavity. These olfactory cells are spindle-shaped receptors surrounded by a moistened mucous

secretion. Each cell is connected with a sensory nerve fiber which combines with other similar afferent fibers to form the olfactory nerve.

All smell stimuli are of a gaseous nature, and reach the receptors via air currents through the nose and mouth. Sniffing odorous substances greatly increases smell sensitivity, since the usual eddy currents in the mouth and nose do not reach the uppermost recess of the nasal cavity. It has been estimated that there are about 60,000 odorous substances, including both organic and inorganic chemical compounds. Most isolated chemical elements, and a few compounds, are entirely odorless.

Qualities of Smell. According to the best introspective studies, there are six independent and distinguishable primary

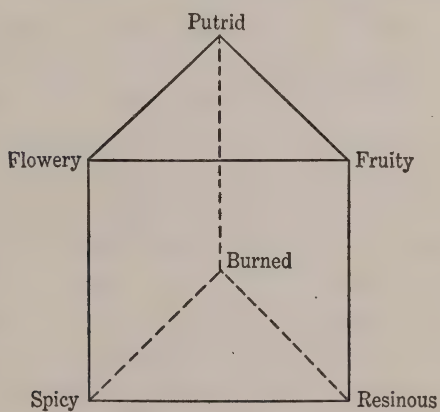


FIG. 91. The Smell Prism.

The surface of this triangular prism shows the relationships between the six primary odors: flowery, putrid, fruity, spicy, burned, and resinous. Many intermediate smell qualities and mixtures can be represented as lying on the surfaces and edges of the prism between the extremes of these six primaries.

odors, which are named *fruity, flowery, spicy, putrid, burned,* and *resinous.* These terms serve to indicate substances that give characteristic odors of the six types. This classification is represented by a triangular prism (Fig. 91), in which a

primary odor lies at each apex, and the mixed odors or intermediate smell qualities lie on the edges and surfaces of the prism.

There is a large variety of possible smell mixtures, since several primary odors may be combined in various quantities to produce a given olfactory experience. Most substances give off mixed odors. The odor of coffee is intermediate between resinous and burned, but has a small trace of spicy. It is the minor spicy element, however, that makes a large part of the difference between "good" and "bad" coffee. The odor of onion is largely putrid, but contains traces of flowery, spicy, and burned. The olfactory receptors are extremely sensitive to minute quantities of chemical substances. Therefore the number of combinations of the six elementary odors in all possible intensities is very large.

As with the sense of taste, some olfactory mixtures tend to show *compensation*, in that a weaker component is suppressed by a stronger odor. Two odorous substances may be mixed to get a weak fusion in which each element is reduced in intensity. The application of eau de Cologne to combat unpleasant bodily odors is an example of compensation.

Smell Adaptation. Olfactory adaptation is the most rapid of all examples of sensory "fatigue," most odors reaching a state of complete adaptation within a few minutes. Different odors have different speeds of adaptation; as a rule, the stronger an odor is, the more rapidly it will become adapted. Although sniffing odors increases sensitivity momentarily, it hastens adaptation. The importance of smell adaptation in everyday life is quite evident, as exemplified by the way in which workers in tanneries, cheese factories, and fish markets become insensitive to their particular environment. The sense of smell often enables an individual to avoid dangerous environments, such as the presence of harmful gases. If immediate heed is not given to the warning, injurious effects may result, since the odor soon becomes imperceptible.

CUTANEOUS EXPERIENCES

The Structure of the Skin. The cutaneous experiences are aroused by a stimulation of the skin on the surface of the body. Unlike the more specialized sense receptors for vision,

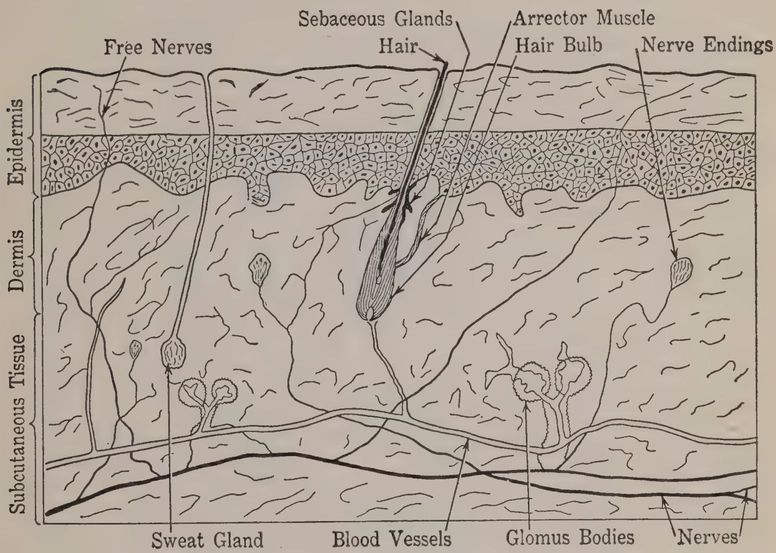


FIG. 92. Cross Section of a Portion of the Human Skin.

This diagram shows the layers of the skin with their typical structures. The epidermis, the outside horny layer of the skin, serves primarily as protection for the second layer, the dermis. There is no clear division between the dermis and the subcutaneous tissue. These contain the various nerves, hair bulbs, sweat glands, sebaceous glands, muscle tissue, and blood vessels. Associated with the blood vessels are glomus bodies which are supposed to act as "thermostats" in controlling skin temperature. There is some evidence to show that the glomus bodies may serve as receptors for pressure and temperature sensations. The subcutaneous tissue is composed largely of fat and is not usually considered a part of the true skin.

hearing, taste, and smell, the skin is a mosaic structure which gives rise to several different qualitative patterns of perceptual experience with different modes of stimulation. The skin is not uniformly sensitive, but has various sensory mechanisms scattered throughout its structure, each type of which is sensi-

tive to certain classes of stimuli and to different degrees of stimulation.

Anatomically, the skin consists of two main parts (Fig. 92), the *epidermis*, or outside horny layer, and the *dermis*, which contains the various nerve endings, hair bulbs, sweat glands, sebaceous glands, muscle tissue, and blood vessels. As can be seen from the figure, some of these mechanisms extend down into the subcutaneous tissue, which is usually not considered a part of the true skin.

The epidermis is hard, oily, and very irregular in its contour; when observed under the microscope, it gives the appearance of deep valleys situated between high ridges. It is extremely pliable, making deformation relatively easy when a mechanical stimulus is applied. The skin varies in thickness on different parts of the body. The thinnest region is the eyelid, where it is about 0.5 of one mm. in thickness. The skin is thickest in those regions that are less protected from mechanical contacts, such as the palms of the hands and the soles of the feet, which have a thickness of around 4 mm.

Cutaneous Stimuli. The skin is sensitive to four different physical types of stimuli: mechanical (such as a sharp needle), electrical (such as shocks from electric current), chemical (such as an acid), and thermal (hot or cold objects). Any one of these types of stimuli can give rise to experiences of four different classes of cutaneous qualities: *pressure*, *pain*, *warmth*, and *cold*. The kind of sensation aroused depends not only upon the type of stimulus, its strength, and the length of time it is applied, but also upon the particular skin area excited and the local conditions of the skin at the moment of stimulation. In exploring the skin point by point with different types of stimuli, one finds that it is not uniformly sensitive, but that some spots yield one qualitative pattern of experience and others give a different type of sensation. Again, some spots are sensitive to relatively weak stimulation, whereas others respond only to very intense stimuli.

Pressure Qualities. Pressure experiences are aroused when

a mechanical stimulus makes contact with the skin in a manner that produces deformation. This deformation can be either positive or negative. Pulling out the skin brings about virtually the same feeling as that which is aroused by depressing it. Therefore, any stimulus that gives rise to a sufficient deformation of the skin will elicit various pressure qualities, the particular quality depending both upon the degree of deformation and upon the particular skin area stimulated.

When the skin is depressed slightly by a weak punctiform stimulus such as a horsehair, or is brushed lightly with a feather, the resulting experience is a pressure-like quality known as *tickle*. Tickle is a vague, light pressure quality, not well localized. Depressing the skin much further gives an experience described as *neutral pressure*. This feeling is somewhat better localized than tickle, and can be described as a solid pressure quality confined to the general area of stimulation. When a mechanical stimulus of intermediate intensity is applied, a quality called *contact* is perceived. These facts indicate that a relationship exists between the intensity of the stimulus, which causes different degrees of skin deformation, and the quality of the aroused experience.

The relationship of stimulus intensity and qualitative experience is not uniform because the different regions of the skin differ in sensitivity. There are *pressure spots* on the skin that yield the experience of a well-defined pressure quality to even mild stimulation. The sensations aroused by stimulating these spots differ from the experiences of neutral pressure. Neutral pressure is much better localized spatially than is tickle or contact, but these pressure spots are even better localized. They feel like a small solid mass just beneath the point of stimulation. The distribution of these pressure spots varies greatly for different regions of the body. There are many on those regions of the skin where hairs grow, chiefly on the "windward" side of the hairs. If a hair on the skin is cut short and its stub is moved, there will be a distinct pressure quality, probably because the hair acts as a lever that

excites a sense receptor near its base. However, pressure spots are not limited to the hairy regions, but are scattered variously in hairless skin areas. There is a relationship between the structure of the epidermis and the number of the pressure spots. The epidermis on the palms of the hands and soles of the feet is thick and cornified, and these regions have many pressure spots. On other sections of the body where the epidermis is relatively thin and of finer texture there are very few pressure spots. The middle of the back is such an area, and contains only a few isolated pressure spots.

Two-point Limen of Pressure. One method of obtaining data on cutaneous sensitivity of the various regions of the skin is to observe the *limen of duality*. When two points on the skin are stimulated simultaneously, they will give the feeling of only one point unless they are separated by a certain distance. The minimum distance that two points must be separated in order to be felt as two is a measure of the "two-point limen." This limen is very great on the middle of the back, for here two points must be as much as 4 or 5 centimeters apart in order to be experienced in duality. On the other hand, the lips and the tips of the fingers have a very small limen, the "twoness" being experienced in some cases when the separation is less than a millimeter. Regions rich in pressure spots yield liminal values which are very small, while the regions relatively insensitive to pressure give large two-point thresholds.

Cutaneous Localization. The perception of tactual spatial relations is not as definite as visual localization, but is more accurate than auditory localization. The localization of cutaneous sensations is comparatively easy with respect to the general region of the skin being stimulated. One can tell without error whether a fly alights on the back of the neck or on the forehead. It is easy to detect whether a pain comes from the foot or the hand, for there are certain *local signs*, based on the positions of the receptors in the skin, that give a clue. Local signs are effective because the individual has learned

through past experience that a certain sensation pattern indicates a certain source of stimulation. The importance of learning in cutaneous localization is often underestimated because people are so familiar with this accomplishment. However, the significance of learning to localize a sensation can be seen in certain examples. One may have a painful earache and mistake it for a toothache. But if this pain continues periodically and is diagnosed as an earache, one will learn to feel it as coming from the ear and not from the tooth.

Although the general localization of a touch quality is fairly easy, exact point localization is less accurate. If a blindfolded subject is touched at some point on the hand, he will be able to tell the general area in which he was stimulated, but not the particular point. Practice in localizing a given point of stimulation serves to reduce the error of judgment, showing again the effect of learning. Errors are always smaller on those regions of the body that are most frequently exposed to mechanical contacts, like the hands and feet.

Vibration. When an intermittent mechanical stimulus, such as an oscillating tuning fork or an electrically driven vibrator, is applied to the skin the experience has an "intermittent pressure" quality which is called *vibration.* The regions of the skin which have many pressure spots are very sensitive to vibration. Those regions that are relatively insensitive to pressure are not very sensitive to vibration.

One of the best methods of exploring the skin for pressure spots is the use of alternating electrical currents. When pressure spots are stimulated with these currents, the sensations aroused are distinctly vibratory, indistinguishable from those produced by a mechanically vibrating body. If there are no pressure spots in the skin region stimulated by the electrical currents, the resulting experience is that of burning pain.

The distribution of vibratory sensitivity over the surface of the body is the same as the distribution of pressure sensitivity. The palms of the hands and soles of the feet are the most sensitive general areas. The upper limit of vibratory

sensitivity, that is, the highest frequency at which the individual pulsations can be felt, ranges from around 2,600 c.p.s. (cycles per second) at the finger tips to only a few hundred c.p.s. on fairly insensitive regions such as the middle of the back.

Very strong vibratory stimuli will set up feelings of vibration in almost any region of the body, just as a feeling of pressure may be induced in almost any area provided the stimulus is intense enough. In an engine room one can feel the vibrations of the engine throughout the body. This is because the bones are made to vibrate, which in turn transmits vibrations to the tissues that have pressure-sensitive end organs. While listening to a pipe organ one not only hears the music, but also feels vibrations throughout the body, chiefly in the "pit of the stomach." Some deaf individuals have been able to learn to appreciate music merely through vibratory feeling, Helen Keller offering a notable example of such an accomplishment.

Pain Qualities. A very intense stimulation of any sense organ or sensory nerve will arouse various feelings of pain. If the eye is subjected to an extremely strong light, or the ear to a very loud sound, pain is felt. Cutaneous pain is thus aroused, in the main, by excessively strong stimuli, either mechanical, electrical, thermal, or chemical. Pain is not to be considered solely as the result of the activities of special sense receptors, but often as a different type of nerve discharge brought on by a strong stimulation of any sense receptor. There are two types of nerve discharge that may result from the stimulation of various sense organs in the skin. Mild mechanical stimuli set off nerve discharges in a rapid regular rhythm, and give rise to sensations of contact or neutral pressure. When the stimuli become intense, the nerve impulses given off are slow, irregular, and non-rhythmic, and pain is experienced. As a gradually increasing pressure of a punctiform stimulus is applied to the surface of the skin, *tickle* is sensed

first, then *contact*, then *neutral pressure*, and finally *pain*. Pain is usually the end result of any type of excessive stimulation.

The outer horny layer of epidermis on the feet and hands acts as a protective buffer against stimuli that might otherwise cause pain. However, the conjunctiva of the eye and the inner joints of the knees and elbows do not have such a protective covering, and here pain is aroused with fairly light stimuli. Under normal conditions the finger tips yield only feelings of vibration when shocked by mild alternating electrical currents, but once the protective epidermis has been removed pain is easily aroused. Further, there are pain spots on the skin where free nerve fibers come near the surface. These free nerve endings are unusually sensitive to stimuli and respond with irregular nerve discharges, resulting in feelings of pain.

There are many qualitatively different pain experiences for which descriptive terms are employed. Dallenbach has prepared a list of such descriptive terms which designate experiences of pain as: achy, heating, biting, boring, bright, burning, clear, cutting, dark, digging, dragging, drawing, dull, fluttering, gnawing, hard, heavy, itchy, nipping, palpitating, penetrating, piercing, pinching, pressing, pricking, quick, quivering, radiating, raking, savage, sharp, smart, squeezing, stabbing, sticking, stinging, tearing, thrilling, throbbing, thrusting, tugging, twitching, ugly, vicious. Most of these terms describe the temporal and spatial course of the experience and its fusion with the other cutaneous qualities of pressure, warm, and cold. The particular pattern of pain experience that is aroused depends upon the type of stimulus, its intensity, and the particular body area affected. The sensitivity to pain is greatest in the more vital regions of the body, and serves to give warning to the organism of any harmful consequences that may result from a destruction of tissue by cuts, wounds, or disease.

Warm and Cold Qualities. When adequate thermal stimuli are applied to the skin, they give rise to two characteristically different qualities of experience, the feelings of *warmth* and

cold. When the skin is touched by warm or cold objects the perceptual experiences aroused depend not on the absolute temperature of the physical stimulus, but on the differential relationship between the temperature of the physical stimulus and that of the skin at the moment of stimulation. That is to say, a physical stimulus of the same temperature as the skin will arouse a thermally indifferent experience, being neither warm nor cold. The temperature of the skin at the point of indifference is known as *psychological zero* (or *physiological zero*). The physical value of this psychological zero point shifts up and down according to one's health, activities, and environment, and also varies from one part of the body to another, being lower in those regions that are sparsely supplied with blood. Under normal conditions, the psychological zero point on most regions of the skin is about 33 degrees Centigrade (91° F.). The zero point may be lowered by cold baths and raised by warm ones. Thus, if the left hand is placed in warm water and the right hand in cold water, and after a few minutes both hands are placed in water of neutral temperature, the water will seem cold to the left hand and warm to the right hand. This contrast occurs because the zero point has been raised in the left hand and lowered in the right, so that the water of neutral temperature is now above psychological zero for one hand and below for the other.

As the temperature of a stimulus is increased above psychological zero, it will arouse a sense of warmth which grows more intense as higher temperatures are reached. Above about 45 degrees Centigrade (115° F.) pain begins to appear also, so that the experience evoked by a very hot object includes pain as well as warmth. Similarly, when temperatures applied to the skin are below the psychological zero point, experiences occur which are graduated from cool to cold. Below a temperature of about 10 degrees Centigrade (50° F.) some pain is also stimulated; very cold objects provoke notably painful sensations.

Temperature spots on the skin are demonstrated as easily

as are pressure and pain spots. When a metal point which is a few degrees above the temperature of the skin is drawn across an area, certain diffused spots will be found that give a more vivid experience of warmth than the adjoining regions. Similarly, if the point is cooler than the skin, tiny cold spots will be found. Cold spots are less diffused than warm spots and there are more of them per unit of area. The number of warm and cold spots found on any region of the skin depends largely on the intensity of the stimulus. The more intense the stimulus, the greater the number of spots that will be found.

An interesting phenomenon occurs when a very warm stimulus is placed on a cold spot. The sensation aroused is cold, although the stimulus is warm. This is referred to as *paradoxical cold.* With somewhat more difficulty *paradoxical warmth* can be aroused by stimulating a warm spot with a cold stimulus. However, the feeling of warmth is not clear cut, but is better described as a "cold warmth." This fusion of warmth and cold approximates a new qualitative pattern of experience which becomes quite distinct when adjacent alternate areas of the skin are excited simultaneously by warm and cold stimuli. This new quality is called *psychological heat.* It is difficult to analyze; it feels neither warm nor cold, but rather possesses an intermediate quality between the two, combined with a complex pattern of pressure and prickling pain.

Cutaneous Adaptation. Cutaneous adaptation means a change in the quality, or clearness, or a diminution of the intensity of a touch experience, which occurs with continuous unchanged stimulation. Adaptation time is the time which elapses between the onset of continuous stimulation and the point at which the sense organ no longer responds and the stimulus is no longer experienced.

The various pressure sensations fade very quickly after the removal of the stimulus, but adapt somewhat more slowly when the stimulus is allowed to remain in contact with the skin. Adaptation is most noticeable with weak stimuli. A weak stimulus that arouses only tickle will adapt much more quickly

than a more intense stimulus that sets up contact or neutral pressure. There may be a complete adaptation to a stimulus that keeps the skin depressed, but a sensation may be felt when the skin moves back to a normal position after the removal of the stimulus, since the return movement causes the pressure experience to recur.

Adaptation depends upon a constant, motionless application of the stimulus. Any rapid change in the stimulus will interfere with the process of adaptation. It is possible to apply a weak stimulus to the skin and increase the intensity of it so gradually that adaptation sets in and continues from the onset of stimulation. In this manner the stimulus may become very intense without arousing any sensation whatsoever, the sense organ adapting as fast as the change takes place. Adaptation of pressure sensations is an important factor in everyday life. People do not sense the pressure of their clothing or of rings on the fingers, or that exerted on the nose and ears by spectacles. When eyeglasses are first worn, they arouse a number of often unpleasant touch qualities which soon disappear with adaptation.

Pain qualities also undergo adaptation provided the stimulus intensity remains constant. The pain that is aroused from the prick of a needle in the skin adapts gradually into qualities of pressure and eventually to indifference. However, most of the pain experiences aroused in everyday life do not undergo adaptation since the stimuli causing the pain seldom remain constant. Pains aroused by overstimulation of the sense organs do not cease until the stimulus is removed, or until the sensitive tissue is destroyed to such an extent that nerve discharges can no longer be elicited. Adaptation is reached in warm and cold sensitivity at the point of thermal indifference. Temperature adaptation is reached only when the stimulating conditions are constant. The hand may be held perfectly still in warm water until the feeling of warmth has just ceased, but a movement of the hand may make the water feel warm again. It is possible to increase physical temperature so slowly that the

psychological zero may be raised in direct relation to the increasing intensity of the stimulus.

Theories of Cutaneous Sensitivity

Two theories have been proposed to explain the neural mechanisms which mediate the four general qualities of cutaneous experience, the *qualitative theory* and the *quantitative theory*.

Qualitative Theory. The qualitative theory postulates a spatial distribution of four separate and distinct end organs which mediate the four cutaneous qualities. This theory seems right at first examination, since it provides a specific end organ for a specific quality. It is also supported by the fact that there are without doubt distinct pressure, pain, warm, and cold spots variously scattered throughout the skin. The theory states, then, that the skin is a mosaic corresponding to the distribution of receptors, a receptor for pressure here, one for pain there, and others for warm and cold, with the areas between these receptors insensitive. It has been supposed that Meissner corpuscles mediate pressure, free nerve endings pain, Krause end bulbs cold, and Ruffini endings warm. The term "qualitative" is used since a given end organ, whenever stimulated, will yield one and only one kind of quality of experience.

Many experiments in which the skin has been excised and examined under the microscope have revealed that the spots of sensitivity do not correspond in kind or number to the assumed end organ. Some few experimenters have found evidence that Krause end bulbs mediate cold and the free nerve endings pain, but the evidence is still far from conclusive. Anatomical studies therefore give little evidence to support a strictly qualitative theory.

Quantitative Theory. The quantitative theory, proposed by Nafe, does not postulate specific end organs for the four different qualitative experiences. As has been pointed out earlier, one may stimulate any point on the skin with a needle and find different qualitative experiences with different degrees of

stimulation. With mild stimulation tickle is perceived, while gradually increasing the stimulus arouses in turn patterns of contact, neutral pressure, and finally pain. According to Nafe, these different qualities of experience are aroused because of a "quantitative" difference in the patterns of nerve discharge. The experience obtained from any given stimulation can be analyzed in terms of three primary attributes of intensity, duration, and area, which determine the nature of the neural discharge, and hence define the experience. A change of any one or all of these three properties will modify the experience, and give a different quality of perception. Therefore, the three different qualities of pressure and that of pain result not from the stimulation of different end organs, but from a quantitative change in the nervous discharge from the same receptors. Both the frequency and regularity of the impulses determine the felt experience. Pain can be elicited from a pressure spot if the intensity of the stimulus is great enough to cause a modification of the nerve discharge, making this discharge non-periodic and irregular.

The experience of *warmth*, according to the quantitative theory, depends upon the *relaxation* of vascular muscles and the consequent pattern of sensory nerve discharge from these muscles. The experience of *cold* depends upon a *contraction* of these vascular muscles. An excessive contraction of these muscles will arouse *pain*. The feeling of psychological *heat* depends upon the simultaneous or closely successive relaxation and contraction of vascular muscles in fairly close proximity. Thus the quality of the experience aroused will depend upon the type of stimulus (warm or cold), its intensity, and the effect it has on the neuromusculature.

The quantitative theory thus holds that each quality of cutaneous experience is determined by the pattern of nerve discharge that reaches the somesthetic area of the cortex, and not from the stimulation of specific end organs and fibers each of which has its individual "label." Sensory fibers can, however, be grouped according to their size and their rate of nerve

impulse conduction. The smallest and slowest fibers need the strongest stimuli to excite them. For this reason, the smaller nerve fibers are concerned chiefly with pain, and the larger ones with pressure qualities; but this does not "label" them as strictly "pain" and "pressure" fibers respectively. The vascular muscles may be regarded as the mechanisms for mediating feelings of warmth and cold, not because of a specificity attached to them, but because they give one characteristic pattern of nerve discharge when relaxed and another when contracted. The quantitative theory of cutaneous sensitivity overcomes many of the known objections to the qualitative theory. As yet, however, the theory is on trial pending the discovery of additional evidence.

Kinesthetic Experiences

The Perception of Movement. The movements made by the muscles, the tendons, and the joints arouse certain patterns of perception which are called *kinesthetic experiences.* The kinesthetic sense is commonly referred to as the "muscle sense." The muscles not only are supplied with motor nerves which bring impulses to cause their contraction or relaxation, but they also are connected with many sensory nerves which record their movements. Any movement of a muscle, tendon, or joint sends sensory impulses to the brain and arouses kinesthetic experiences. These impulses are initiated by the proprioceptors, which were described in Chapter II.

The importance of kinesthesis in everyday behavior cannot be overestimated. There are few situations in life in which some muscles are not functioning in one way or another. An individual may be deprived of all the experiences mediated by the more "specialized" senses of sight, hearing, smell, and taste and still be able to make certain vital adjustments to life situations by means of kinesthesis. Many instances are recorded of how blind and deaf persons learn to adjust themselves to familiar surroundings through kinesthetic cues. Dr. Gabriel Farrell of the Perkins Institution for the Blind describes how

blind girls learn to use kinesthetic cues in finding their way about the school:

> Outside my office is a long walk leading to the girls' cottages. A little beyond the window the walk turns to go along the end of the building. Many times in the fall I see a girl walk along, hesitate, go back a bit, and then begin to clap her hands. Soon she stops clapping and steps briskly around the corner. She has not yet learned how long that walk is and is getting her bearings by listening for the reverberation from the brick wall of the building. When the vibrations of clapping cease to return, she knows that she is beyond the building and that the turn can be made. This happens only at the beginning of the school year when there are new girls. The older pupils have learned the way, and soon the new ones establish landmarks and develop muscular memory. . . . It is often difficult to believe that our pupils are without sight when they unhesitatingly run about and unerringly make their way from one classroom to another.[1]

Normal individuals make much use of kinesthetic cues, although they are seldom conscious of them as such because these sensations are associated with those from the other senses. Kinesthetic cues play a primary rôle in walking. The movement of one leg causes a discharge of sensory impulses from the muscles, tendons, and joints of that leg, which are carried to the central nervous system, where associations are made which send motor impulses down to the other leg and cause its movement. An alternate movement of the two legs thus results. A person can find his way in a familiar room easily, and can avoid obstacles even in total darkness, or climb a flight of familiar stairs, entirely on the cues furnished by "muscular memory." The importance of these kinesthetic cues is illustrated in the abnormal condition known as *locomotor ataxia*. This is a disease caused by a lesion of the proprioceptive nerve pathways in the spinal cord that cuts off the sensory impulses from the muscles. Individuals affected by this disease can walk only with great difficulty by watching where they put their feet and using canes. If they close their eyes and are not supported they are unable to keep from fall-

[1] Farrell, G., "How the Blind See," *The Forum*, August, 1936.

ing. Even when they watch the movements of their limbs, muscular coordination is very poor. Such patients typically walk with staggering gait. By employing kinesthetic cues normal persons can learn to judge with a fair degree of accuracy the relative position of the body or of any part of it. With the eyes closed one can tell the distance that the arm has been moved and what its position is.

The importance of muscular "set" in the kinesthetic judgment of weights of objects is illustrated by the size-weight illusion. If two boxes of the same weight are lifted, one in each hand, and they are of equal size and shape, their weights will be judged equal. But if one of them is larger than the other, and their weights are equal, the smaller box will be judged to be the heavier. This illusion in judgment is caused by the fact that the subject involuntarily tenses his muscles and exerts more effort to lift the larger box than to raise the smaller one. Consequently, the smaller box pulls the hand downward to a greater degree, and is felt to be heavier.

Kinesthesis is involved in many other perceptual experiences. For example, when one looks at a near object and then at a far object, his judgment of the distance between the two objects is in part influenced by the kinesthetic cues from the muscles that control accommodation and convergence of the eyes. Auditory experiences are always accompanied by tactual and kinesthetic experiences. Even the higher mental processes of thinking have certain muscular associations. Practically every form of behavior appears to be influenced either directly or indirectly by the kinesthetic sense. Although the sensory impulses generated by muscular movements are often below the limen of conscious experience they nevertheless have a great influence on behavior.

Labyrinthine Experiences

The Perception of Equilibrium. The vestibule and the semicircular canals of the inner ear (Fig. 87, p. 286) provide the sensory material for the maintenance of bodily posture, equi-

librium, steadiness of movement, and general bodily orientation. Labyrinthine experiences which result from changes in movements and positions of the head can be observed in everyday life, as when riding in an elevator, in an airplane, or on the merry-go-round. These experiences result from the stimulation of small hair cell receptors located in the vestibule and the three semicircular canals of the inner ear. In the vestibule, the hair cells are touched at their free ends by tiny stony particles, the *otoliths*. When the head is inclined in any direction, these particles press against the hair cells and bend them, thus sending sensory impulses to the brain along the nerve fibers that are connected to the bases of the hair cells. If a person's head is tilted suddenly he will tend to make head movements in the opposite direction, or if he is pushed off balance he will make an effort to brace himself in the reverse direction. Such compensatory reflex adjustments enable him to maintain bodily equilibrium. The operation of this balancing sense is seldom conscious in everyday life until the disturbance of equilibrium is so great that it initiates an intense stimulation of the otoliths. This occurs whenever one is suddenly thrown off balance and is in danger of falling.

While the otolith receptors of the vestibule mediate the experiences of rectilinear movements of the head, the semicircular canals mediate those of body rotation. There are three such canals; they lie in three planes at right angles to each other, and open into the vestibule at each end. These canals have many hair cell receptors projecting into a liquid medium which is displaced within the canals when the head is rotated. The hair cells are activated by any slight movement of the liquid which is sufficient to bend them. If a person is blindfolded and placed in a chair that can be rotated, he can easily tell when he begins to turn, and in which direction he is going. Rotation is sensed when there is either a positive or a negative *acceleration* of rotation. If the subject is kept turning at a constant speed he soon ceases to sense the movement, but if suddenly stopped he gets the feeling of rotation in the opposite di-

rection. The beginning of the rotation is perceived because there is a displacement of liquid in the canals which bends the hair cells in a direction opposite to the head movement. The feeling of movement ceases when rotation becomes uniform, for the liquid then ceases to move relative to the canal. The experience of reversed rotation is sensed when the body is no longer rotated, since the liquid in the canals remains displaced because of inertia for a short time after rotation ceases (Fig. 93).

Labyrinthine experiences are associated in many ways with kinesthesis and other perceptual experiences. The sensory impulses aroused in the vestibule and canals of the inner ear bring about an association in the central nervous system that sends motor impulses to activate the skeletal musculature of the body. These muscular movements in turn elicit kinesthetic impulses which become associated

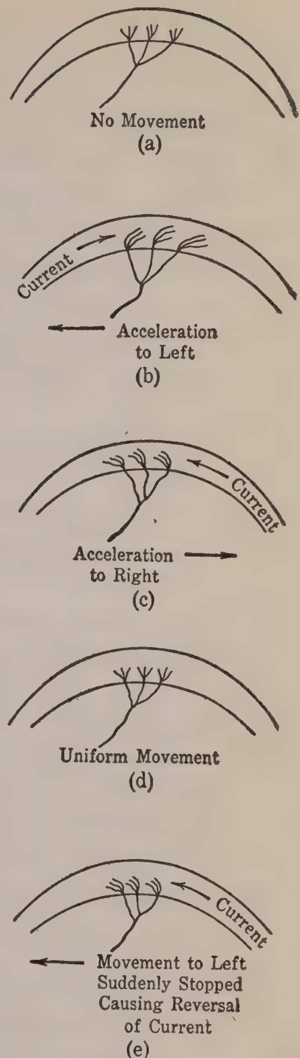


FIG. 93. Action of the Semicircular Canals During Bodily Rotation.

These diagrams show how the sensory hair cells of the semicircular canals are stimulated by the liquid current within the canals when the head is rotated. (a) Here the head is stationary, the hair cells remain in an upright position and no stimulation occurs. (b) When the head is rotated to the left the liquid in the canals flows toward the right bending the hair cells in that direction. This gives the subject the perception of turning to the left. (c) Here the acceleration is to the right. (d) Since the hair cells bend only under conditions of positive or negative acceleration, uniform rotation of the head does not produce a labyrinthine stimulation. (e) When the rotation to the left is suddenly stopped, a reversal of the current takes place and the subject has an illusion of rotation to the right.

with the impulses directly aroused by labyrinthine stimulation. For this reason it is difficult to analyze labyrinthine experiences as particular qualities in themselves. Certain visual and organic experiences are also frequently associated with labyrinthine experiences, as when feelings of nausea and dizziness often accompany body rotation. The sensation of things moving around and around after rotation is commonly accompanied by an oscillatory movement of the eyes known as *nystagmus*. The close association between labyrinthine and visual experiences is evidenced by the fact that feelings of dizziness can be aroused by rotating a patterned visual field around a subject while he is in a stationary position. Looking down from a high place often brings about feelings of dizziness, and consequently of interrupted equilibrium. Again, labyrinthine experiences may be aroused by circulating warm and cold water through the outer ear, or by passing electrical currents through the mastoid region of the head.

There is some question as to whether complete and lasting adaptation to labyrinthine excitation can be attained. Elevator operators report that they still sense "feelings of falling" with a rather sudden drop of the elevator, even after years of experience. On the other hand, experienced sailors seldom have any after-effects of the motion and churning of a boat, whereas the novice may feel the effects of a boat ride for hours afterward. The illusory movement of the environment, *visual vertigo,* experienced after rotation by persons not accustomed to it, is not perceived by whirling dancers, figure skaters, acrobats, and others who frequently engage in bodily rotation.

The Organic Experiences

The organic experiences include such feelings as hunger, thirst, and others associated with respiration, digestion, and sexual excitement. Of these intra-organic experiences, hunger and thirst have been studied most extensively.

Hunger and Thirst. Food and water are stored in the tissues of the body to satisfy bodily needs. As need arises, these

stored reserves are set free for use and must then be replenished. The experiences of hunger and thirst serve to warn the organism to care for this supply.

Hunger can best be described as a disagreeable ache or pang located in the pit of the stomach. A few hours after the

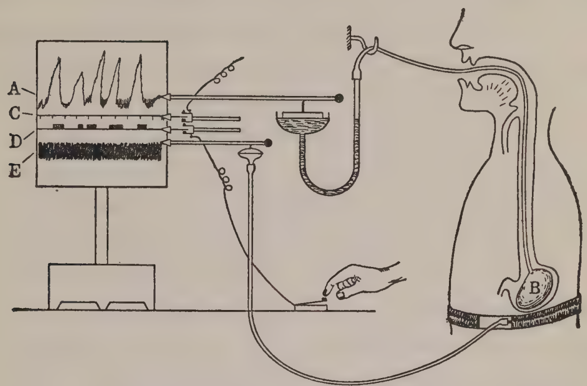


FIG. 94. Method of Recording Gastric Hunger Contractions.

A rubber balloon (*B*) is placed in the subject's stomach. After the balloon is inflated through the rubber tube leading from the subject's mouth, the tube is connected to a manometer in which a cork floats. The cork is attached to a recording lever which moves up and down with each movement of the walls of the stomach. These gastric contractions are shown recorded on the kymograph at *A*. When the subject feels a hunger pang he presses the electric key actuating another writing lever. Thus the hunger sensations are recorded on the kymograph at *D*. The time record in minutes is recorded at *C* by a lever connected to a timing device. *E* shows a pneumograph record of the contractions of the muscles of the abdominal wall. This experiment shows that hunger results from the periodic contractions of the gastric muscles, and not from the movements of the abdominal wall. (After W. B. Cannon, "Hunger and Thirst," in *Handbook of General Experimental Psychology,* Clark University Press.)

food contents have passed from the stomach, there are sharp periodic contractions in the gastric muscles of the stomach wall. Cannon has shown that these contractions give rise to the experience of hunger. To demonstrate the experience of hunger, a subject swallows a rubber balloon attached to a tube which is inflated with air (Fig. 94). The tube is attached to a recording lever which moves up and down with each movement of the walls of the stomach, recording them on a slow-

moving kymograph. Whenever the subject feels a hunger pang, he presses an electric key, thus actuating another writing lever connected with the kymograph. A third and fourth writing lever record the time, and any movements of the external muscles of the abdominal wall. The records from this experiment show that each series of contractions of the gastric muscles is accompanied by the experience of a hunger pang. The subject experiences the pang only when the muscular contraction has nearly reached its peak. The experience of hunger therefore is not the cause of the contraction, but the contraction is the cause of the hunger experience.

Any stimulus that will cause the relaxation of the gastric musculature will relieve the hunger pang. Food relieves hunger since it causes such a relaxation. Even a rubber balloon inflated tightly in the stomach will relieve the feelings of hunger. Very vigorous muscular exercise will relieve hunger temporarily by inhibiting the contractions of the stomach walls. Strong emotional upset temporarily abolishes these gastric contractions, and smoking weakens them.

Thirst is an unpleasant feeling of dryness and stickiness of the inner surface of the mouth, the back part of the palate, the root of the tongue, and the throat. Circumstances which result in the rapid evaporation of moisture from the mouth and throat, such as breathing hot, dry air, prolonged speaking or singing, or eating dry food, will lead to the experience of thirst and the desire for something to drink. Besides these local conditions there are certain general bodily states which bring on thirst. Excessive perspiration or an abnormal discharge of water from the kidneys make the experience of thirst very intense.

There are many other complex qualities of organic experience that are difficult to analyze, such as feelings of stuffiness or suffocation. A number of intra-organic disturbances arouse sensations of pain. These are probably due, like cutaneous pain, to intense, slow, and irregular neural discharges in any sensory fibers with which the organs may be supplied. Some organic

pains are localized correctly at the seat of the disturbance, as in the case of a stomachache. Others are *referred pains*, in which the pain is experienced in some part of the body remote from the region of stimulation, but usually along the path taken by the discharging nerve fibers. Almost all headaches and many backaches are referred pains. The point to which a pain is referred is usually consistent, a fact that is of great aid in medical diagnosis.

Chapter XII

REMEMBERING

The Nature of Memory

Remembering is a most common human experience that functions daily in the life of every person. One remembers an appointment, remembers what he had for breakfast, remembers a formula needed in the solution of a problem, or remembers how to operate a machine. These various acts are not all exactly alike psychologically, but they have a significant common factor. In each case the *present* experience or behavior is determined by something that has happened in the *past*. Remembering, therefore, is a present knowledge of some event or fact that has occurred before. This knowledge may consist of an experience that has a more or less accurate resemblance to a past event, or it may occur in action, as when a person goes to keep his remembered appointment or succeeds in operating the machine that he has worked with on a previous occasion. In most instances both experience and behavior give evidence that remembering has occurred, although one may exist occasionally without the other.

The Processes of Remembering. In every total process of memory two essential steps are found, separated by an interval of time. The first step is *acquiring* or learning, the action by which the initial knowledge is obtained. The second step is *recalling* the event at some later time. Everything that is remembered must first be acquired, but the process of memory is not complete until the acquired material has been recalled.

In addition to the two essentials of acquiring and recalling, two other parts of a complete act of remembering are some-

times described separately. One is *retaining*, which designates the condition that exists between the time of acquiring and that of recalling. Retaining cannot be described apart from recalling, however, for recall is the evidence that retention has existed. The other aspect of remembering is *recognizing* that an event has occurred in one's past experience. Recognizing may be considered as a variation of the more fundamental process of recalling.

Remembering Is a Stimulus-response Activity. Both acquiring and recalling are *activities* of the organism, not just "states of mind." An incorrect popular interpretation holds that remembered events are "stored away" ready to come forth when needed. This notion ignores the fact, amply supported by experimental findings, that *remembering is a stimulus-response process.*

It is easily seen that acquiring is an act of attaching a response to a stimulus. When he learns a lesson, a student acquires a set of answer responses to the question stimuli that may be asked at a later time. When an individual observes an event, he makes perceptual responses to the many stimuli that are present. Because of this connection, some of the stimuli become capable of arousing the total response at a later time.

Recalling is also always a response to a stimulus. This is very obvious in some examples, as when the stimulus "discovery of America," accompanied by a set to remember dates, arouses the response "1492." In other instances the stimulus may be subtle and hard to locate, but it nevertheless exists. Whenever we remember an event, some present stimulus has served to "remind" us of it. Without that particular stimulus we would have thought of something else. The effectiveness of a stimulus to evoke a certain recall response is determined by its previous association with that response. The recalling is always a present act, however. It has reference and a resemblance to the past, but it is not merely a reinstatement of what has occurred before.

Perceiving, remembering, thinking, and imagining may be

regarded as a hierarchy of stimulus-response activities of increasing complexity, all of which involve awareness or subjective experience. Perception requires a present stimulation from the object or from some part of it. Remembering permits an awareness of things that are not immediately present to the senses, but which are represented by substitute stimuli. The still more complex processes of thinking and imagining, to be described in the next chapter, involve the manipulation and modification of remembered experiences.

Acquiring

Acquiring Is Associative Learning. Since acquiring is learning, its general principles have already been presented in Chapter V. One of these principles, the law of contiguity, states that a stimulus and a response must occur together if learning is to take place. This is the most fundamental condition for acquiring. For example, let us examine the act of learning that "9 times 7" equals "63." The learner is stimulated by showing him "9 times 7" or by saying it to him. At the same time he must be made to write, say, or think the response "63." This latter, of course, must be elicited by some original stimulus of its own, such as seeing or hearing a "63" written or spoken by the teacher. After "9 times 7" has accompanied "63" for a number of times, it becomes capable of stimulating this response. Following this learning process, "9 times 7" alone and unreinforced by any other stimuli is sufficient to call forth the desired answer. A *part* of the whole original stimulus pattern, $9 \times 7 = 63$, has become capable of eliciting the *whole* response. This is exactly the same process as the conditioned reaction. The whole situation "shock plus bell" evokes leg retraction originally, but after training, "bell" alone can call forth the same response.

An extension of the above formulation is especially useful in describing the process of memory. A person who witnesses an automobile accident is assailed by a large number of stimuli to which he makes a complex but unified perceptual response.

He sees, hears, and perhaps feels (cutaneously) many elements of the scene. Moreover, there are many other less well-noticed stimuli that arise from his own body, such as the visceral changes of emotion, and the kinesthetic experiences from his muscles and joints that result from his attitude or posture of recoil or horror. These many stimuli, which may be designated A, B, C, D, E, F, etc., evoke a total complex perceptual response N, O, P, Q, R, S, etc. In the future, *any* of these associated stimuli such as A *or* B *or* C, etc., may evoke a response that is a recall of the entire incident. The individual may be "reminded," that is, stimulated, by seeing a car, by hearing the screech of brakes, by hearing the word "accident," or even by assuming for some other cause the bodily posture that he had at the time of the accident. Diagrammatically:

In Acquiring	In Recalling
$\left.\begin{matrix}\mathrm{A}\\\mathrm{B}\\\mathrm{C}\\\mathrm{D}\\\mathrm{E}\\\mathrm{F}\end{matrix}\right\}\text{ evokes }\left\{\begin{matrix}\mathrm{N}\\\mathrm{O}\\\mathrm{P}\\\mathrm{Q}\\\mathrm{R}\\\mathrm{S}\end{matrix}\right.$	$\text{A evokes }\left\{\begin{matrix}\mathrm{N}\\\mathrm{O}\\\mathrm{P}\\\mathrm{Q}\\\mathrm{R}\\\mathrm{S}\end{matrix}\right.$

The process of *trial and error*, common in other forms of learning, is also found in remembering. The learning of a maze is incomplete and partial at first, and so is the recall of perceptual material that has not been learned adequately. Any person who tries to describe a complicated scene that he has perceived only once will make many errors. His account typically is less than one-third complete, and he even makes positive errors by asserting that he remembers things that did not really occur. This is a disturbing factor in the evidence of witnesses in courts of law. In many situations, as in the learning of lessons, the individual is able to compare his tentative recalls with the material that he is learning. Under optimum conditions, the errors are eliminated, the correct memories become fixed, and the entire recall becomes a smoothly functioning whole, analogous to a well-practiced habit.

Efficiency in Acquiring. Remembering has been the subject of a large amount of psychological research every since the first studies in this field were reported by Ebbinghaus in 1885. There are also a number of special conclusions from general psychological principles that relate directly to efficiency in memorizing. Some of these are concerned with the most advantageous methods by which to learn material that is to be remembered. Other experiments and deductions reveal the conditions that affect retention and recall.

The procedure of a memory experiment is rather simple and direct. To compare two different methods or conditions of memorizing, two groups of subjects are selected. One group learns the material by one method and the other group learns it by another method. After a period of time has elapsed, the subjects of both groups are tested to see how much of the material they can recall. By comparing the average amount recalled by one group with the average amount recalled by the other, the experimenter can determine which method of memorizing is more efficient.

Of course, many precautions are taken in such experiments to prevent irrelevant factors from influencing the results. The subjects are chosen so that the average learning ability of one group equals that of the other. Both groups are allowed the same time to learn the material, unless the amount of practice is the variable being experimented upon. The inherent difficulty of the material that is to be learned is also kept constant. In careful research studies, a series of experiments is performed in which the same subjects learn by different methods, and the same materials are memorized by different techniques.

Six principal conclusions about efficient acquiring can be given. The first four, which concern *motivation, varied stimuli, intensity of response,* and *exercise*, are pertinent to all forms of remembering. They are as useful in remembering names, appointments, errands, and the like, as in learning formal material. The last two, on *whole learning* and *spaced learning*,

are more pertinent to learning bookish material such as an academic assignment or the lines of a play.

Motivation or "Set" in Acquiring. The primary law of acquiring is that a stimulus and a response must occur together in order to be associated. Yet in everyday life this principle often seems to be contradicted, for many events are experienced without being remembered. One of the chief reasons for this is the lack of a motive or set to learn in most situations. Many anecdotes, and some experiments, show clearly that events may be seen or acts performed, even repeatedly, without any observable result of learning or memory. A classic story that illustrates this point is that of the clergyman who had read the services hundreds of times but could not repeat them from memory. He was "set" to read, not to learn, and hence did not remember in spite of a great amount of apparent practice.

Peterson (1916) performed an admirably clear little experiment on the necessity for motivation in acquiring. A class of students was told to copy from the blackboard a list of twenty words "to be used later in an experiment." The list was checked by listening to the instructor read it aloud. Then the students, without warning, were asked to write the words from memory. For comparison, another list of twenty words was then copied and read, but this time the students knew that a reproduction would be demanded. On immediate recall the students did 22 per cent better on the list that they were motivated to learn. Two days later they were unexpectedly told to reproduce both lists again, and they recalled 50 per cent more of the list having the advantage of the preparatory set. With equal amounts of exposure to events, people learn best what they know they have to learn. Evidence such as this indicates the value of definite assignments and of examinations in schools.

Motivation and attitude are as important in informal remembering as in deliberate memorizing. One remembers the parts of an experience that have aroused a reaction because

of their appeal to motives or interests. After walking past the windows of a department store, a man is likely to remember in some detail the showings of firearms or cameras or fishing tackle. His wife can describe equally well the latest styles in hats. Although both have seen the same things, each reacts to the stimuli of special interest and hence remembers them better. On meeting a person, his name is more likely to be remembered if attention is paid to acquiring it; if the name is repeated mechanically without a learning attitude it often cannot be recalled even a few minutes later.

Varied Stimuli. Since recall is a stimulus-response process, efficient learning demands that the desired response be connected to the right stimuli. Learning the name of a person is not just one stimulus-response connection, but several. Not only must the name be remembered when one sees the person, but it must also be aroused by perception of his business, his wife or children, his place of residence, his associates, the time and place at which he was met, and by many other circumstances. If the name is connected to all these facts it can be evoked in many more useful situations than if it is associated only with one or two stimuli. Often a person says, "I know that name well, but I can't think of it now." Usually this statement means that the name is connected to a number of other stimuli, but not to the one that is now present. The same difficulty occurs frequently in school. After an examination students may feel that they "know" the answers to questions that they failed to answer. In such cases, the knowledge may have existed as a response to some other questions, but not to the particular ones asked. To function effectively, information must be connected to all the situations in which it may be used. A few meager associations are not enough.

The practice of attaching a response to varied stimuli has another broader value. If many related informational units are learned together as a coordinated system, each becomes capable of arousing all the others. This interlocking system of knowledge is more useful than any number of separate

associations between single stimuli and responses. In the problem of learning a person's name, for example, if the mention of his business recalls the circumstances under which he was met, his friends, and other associations, then all of these may serve as stimuli to bring forth the response of remembering the name. Any response is more readily aroused if a number of associated stimuli are all brought to bear upon it at once. The function of varied stimuli is even more important in acquiring logical memories, as in the study of a science. If a single formula or fact has been learned in isolation or "by rote," it will function only in a limited number of situations. But if the student has a broad understanding of the significance of the formula, its physical meaning, its derivation, and its relationships to other phenomena, he can recall it in many settings and apply it more usefully and more widely.

Responses During Learning. The general conditions for efficient learning indicate that a person must *make responses* during the process, and that he can recall only the responses that he has made. There is no such thing as "passive absorption" of material, for entire passivity would mean no learning. The quality and intensity of the responses that are made greatly influence the speed and permanence of the learning.

One method for insuring responses during learning is *self-recitation.* The learner attends to the material for a time and then looks away, attempting to recite what he has learned. This is followed by another glance at the material to see if the recitation was correct. The method may be applied to rote learning, in which case the recitation is verbatim, or to reading for general information, the recitation then consisting of the general ideas. Gates (1917) found that as much as 60 to 80 per cent of learning time could be spent profitably in recitation. With both nonsense and meaningful materials, the persons who spent from three-fifths to four-fifths of their time in reciting excelled those who devoted a lesser proportion. This was true both for immediate and for delayed recall. Self-recitation adds to the efficiency of learning for several reasons. It makes

the response more vigorous and more definite. The recitation is the equivalent of a test, and therefore motivates the learner because he knows that he will be tested, by himself, at once. Further, the recitation method utilizes the best values of trial and error learning, since erroneous or incomplete impressions are immediately detected and remedied.

In everyday life an approximate equivalent of the recitation method can be used. The name of a person who has just been met may be repeated to oneself several times. Immediately after a conversation or a business interview it is valuable to review the points to be remembered. These procedures add to the intensity, exercise, and interest of the experience, and give practice in the responses that will have to be recalled later.

Exercise. One of the most evident facts about acquiring is that repetition usually aids the fixation of a stimulus-response pattern and increases the probability that it will function successfully in a later recall. The progress of acquiring during a series of repetitions may be shown by a certain type of learning curve (Fig. 95). In the experiment, the results of which are shown in the figure, a series of fourteen unrelated words was exhibited, each word being exposed for two seconds. After each complete exposure of the series the subject wrote all the words he could remember, and then attended to another repetition of them. After each successive practice a greater number could be recalled, and finally the complete list was reproduced successfully.

The principle of exercise has many practical applications. Lessons must be studied more than once to be retained satisfactorily. The name of a person with whom one has had many contacts is remembered with greater certainty than that of an individual one meets infrequently. All sorts of materials that people have occasion to learn, including telephone numbers, highway routes, poems, musical compositions, and many others, profit from repeated associations.

Other observations indicate that repetition is not always a highly reliable aid to acquiring. It has already been noted

that passages may be read many times without creating any ability to recall them. On the other hand, an incident that has happened only once may be remembered vividly for many years. These findings make it doubtful that repetition is a fixating factor in itself. It is more probable that exercise merely

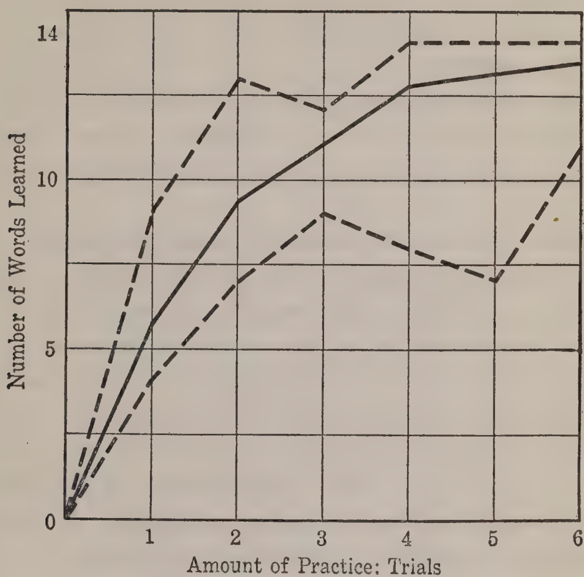


FIG. 95. Learning Curves for Memorizing.

A group of twelve subjects memorized a list of fourteen unrelated words. The graph shows the number of words recalled after each 28-second practice period. The heavy line is the average of the twelve subjects. The upper and lower broken lines are for the best and poorest learners in the group.

gives the factors that really cause learning a chance to operate. Acquiring occurs when the attitude and motivation of the learner are optimal, when the experiences are sufficiently intense, and when the right stimuli and responses are being associated. Exercise gives these desirable conditions a chance to operate repeatedly. Without the other circumstances conducive to learning, exercise itself is unavailing.

Part versus Whole Learning. If one has to memorize a long speech, a poem, or a part in a play, two methods of attack

are possible. One, known as the *part method*, is to separate the material into a number of divisions, such as the stanzas of a poem, and to master each before proceeding to the next. The *whole method* consists in reading the material from beginning to end at each repetition, this process being continued until the desired degree of learning has been accomplished. Common practice, following the line of least resistance, tends to use the part method. A large number of psychological experiments have not settled the issue definitely. In various studies each approach has been found superior under certain conditions, although the balance is somewhat in favor of the whole method.

In typical experiments, poetry, prose materials, and even nonsense have been memorized to advantage by the whole method. On the other hand, most experiments have found a minority of persons who used the part method more effectively, even though the majority saved time by using the other. Some few studies indicate the superiority of the part method for certain applications. A maze so complicated that it was almost impossible to learn as a whole was mastered well when broken into four parts. Another research found that a group of college students remembered more of a chapter when each paragraph was read twice successively than when the whole chapter was read straight through two times.

Since all experiments do not agree on the merits of the whole and part methods, other investigations have been undertaken to determine why one method is sometimes better and sometimes worse. The whole method has the advantage of continuity of thought and meaning, and of making clear the relationships between parts of the material. It also prevents the formation of associative gaps that may confuse the person who has memorized rote material by the part method, when he reaches the end of one of his "parts." The part method has its advantages too. If the material is very long and complex it may be the only practicable way. It also permits visible progress that keeps the learner from becoming discouraged at the be-

ginning of the task. The individual differences in preference for the two methods are most probably due to habit. If a person has become accustomed to learning by an inferior method he does not adapt at once to a superior procedure, but may continue for a time to do better in his habitual way. This factor is believed to explain why some of the briefer experiments with untrained subjects have found the part method superior. In time, of course, a newer and better method of memorizing will gain an advantage over the older but inferior one.

For practical purposes it is often recommended that the learner attack his material by the whole method at first. When all but a few difficult passages have been mastered, he can profitably apply the part method to them, preventing unnecessary repetition of the portions already well learned.

Spaced versus Unspaced Learning. Another issue concerned with the efficiency of acquiring is the *distribution of practice.* If a student has four hours to devote to learning a lesson, is it better to spend the time all at one sitting or to divide it into four periods of one hour each? Psychological research gives a definite answer to this question, at least with respect to some tasks and types of material. The overwhelming evidence favors spaced or distributed learning. For simple types of learning the periods can be quite short. Two twenty-minute drills in arithmetic are definitely superior to one forty-minute period. Even ten-minute periods yield better results than periods as long as forty minutes, although not quite so good as the optimum twenty-minute practice. The exact time that is best varies with the nature and difficulty of the material, but experiments can be conducted to determine the most efficient distribution of practice for any particular subject.

Distribution of practice must be applied in conjunction with other principles of efficient learning. The experiments do not show, of course, that *one* twenty-minute period is better than one forty-minute period. The experiments are concerned only with the way in which equal total amounts of time are dis-

tributed. Also, it is assumed that the material has to be practiced repeatedly, and that it can be covered at least once in the minimum practice period provided. To study half of a chapter at one sitting and the other half at another is "part" learning, not "spaced" learning, and is less rather than more efficient. If material is to be studied only once, the limit of the length of a period is set by fatigue, which varies greatly with the maturity and skill of the learner. With some materials there is a "warming up" period in learning before full efficiency is reached. In studying college subjects practice periods should not be so short that too great a proportion of the time is spent in this preliminary adaptation.

Spaced practice does not always mean equal amounts of exercise distributed at equal intervals. The best distribution is

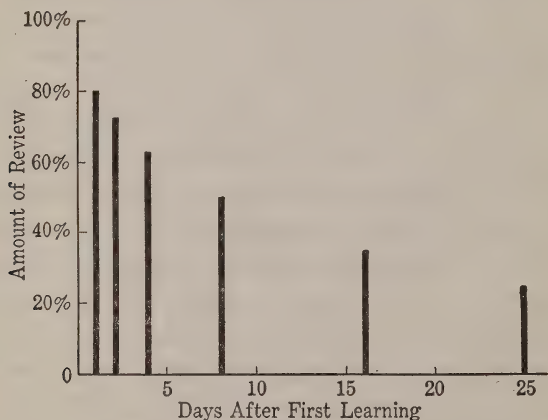


FIG. 96. Distribution of Practice.

It is best to make several thorough reviews soon after the original learning period, followed by decreasing amounts of review at increasing intervals of time. This distribution of practice counteracts the curve of forgetting, which shows the greatest loss of retention in the time immediately following the initial practice.

probably to spend decreasing amounts of time at increasingly spaced intervals (Fig. 96). This practice "strikes when the iron is hot" by having a thorough review soon after the initial learning, followed by decreasing reviews on the days following.

All the findings on the distribution of practice show that "cramming" is very inefficient. Many students would learn more if the large amount of time devoted to last-minute study were spread throughout the term. This is especially true with respect to permanence of retention.

Retaining and Recalling

Recall and Retention. An act of recalling is a response to a stimulus, as has already been stressed. When acquiring takes place a stimulus and response occur together. At the time of recall, the stimulus tends to evoke the same response with which it was associated previously. The stimuli for recalling are sometimes obvious, as when questions are asked. On other occasions they are so fleeting and slight that they tend to escape common observation. In such cases the recall seems to "pop up" from nowhere, but its stimulus is really not absent but merely unobserved. A careful analysis of a sudden memory will often reveal its source. For example, a student reported that as he was starting his automobile at home, he "suddenly remembered" that he had forgotten to shut the furnace door. What stimulated this recall? A review of his mental processes of the preceding few moments gave the answer. He was going to see a friend who was interested in dogs. Another friend had recently been presented with a litter of puppies by his dog, and the puppies were kept in the cellar near the furnace. The train of ideas was then: starting car—to see friend—dogs—other friend—puppies—furnace—unclosed furnace door. Such a chain of experience responses can take place in a few seconds, and may not be remembered for long. All sudden recalls are definitely stimulated, however, and the stimuli may be found if one takes the trouble to search for them.

The assumed condition of the organism between the time of acquiring and that of recalling is called *retention*. It must be understood emphatically that retention does not mean the filing away of actual experiences, or of ideas or images of them. Retention is known to exist only because of its effects upon

later performances. The measure of retention is the subsequent appearance of the learned material. Retaining, then, can be defined best as *the probability of future recall*. This is a quantitative conception, for the probabilities can be expressed numerically. If retention is good, recall is more probable; if it is poor, recall is less likely. Most investigations of retention are studies of the conditions under which recall can be effected.

The physiological basis of retention is not well understood. An act of acquiring probably causes changes of some kind in the nervous system that permit the connection of a stimulus to a certain response. These modifications persist, and are the physiological correlates of retention. The neural changes are the same as those underlying habit formation and other forms of learning. But they are difficult to detect, and have escaped precise investigation. Fortunately, many valuable facts about retention can be determined by psychological experiments, without reference to the neurological causes of the process.

Imagery. Experiences may be remembered as *images*, as well as by words or acts. An image is a subjective perception-like experience that occurs in the absence of the original stimulus for the experience. Images occur in all the modes of sensory experience. A visual image of the color blue, or of a rose, or of the home in which one formerly lived, may be called up. Or we may have auditory images of the timbre of a violin, or of a friend's voice, or of the opening measures of Beethoven's Fifth Symphony. All the other senses may have associated images, for one can recall the taste of quinine, the smell of an onion, the pain of a toothache, the organic sensation in nausea, the kinesthetic experience of moving the arm, or the experience of being rotated. Many images of real events are mixed, involving several sensory elements simultaneously or in succession.

Images are not especially useful for precise recall, for they are not photographic reproductions of the original perceptions and may contain many errors and omissions. Students may be

asked, for example, to form a visual image of the façade of a familiar building. Then they are told to count the number of windows appearing on the image. Different students will arrive at different conclusions, and some will report very vivid images in which a *wrong* number of windows is clearly pictured. To remember how many windows there are, it is necessary to perceive and recall them verbally, as a number. Visual images are of little assistance in such a case. The same is true in other sense departments. It is possible to have a very vivid auditory image of a melody which is quite incorrect in detail.

An exception to the general inaccuracy of imagery has been found in some children. After looking at a complicated picture, a few youngsters can describe it in great detail, even spelling unfamiliar words forward or backward, by reference to their imagery. These rare perfect impressions are called *eidetic images*. The ability to form them seems usually to be lost by the time that adult age is reached.

Tests of imagery show that considerable individual differences exist, as to both intensity and kind. Some persons claim never to have had an image in their lives, while others have frequent, vivid, and varied ones. A preponderance of visual images is reported by some individuals, but others rely more on auditory, cutaneous, or kinesthetic imagery. Careful studies indicate that persons are not divided into definite imagery types. Almost everyone has images of all varieties, but with differences in frequency. In one experiment two hundred stimulus words carefully chosen to elicit all kinds of imagery were used to evoke responses of images which were recorded. Each subject reported almost all varieties of images, visual imagery being the most frequent for the majority of the group. The subject with the greatest proportion of visual images reported that 50 per cent of his responses were of that type, the remainder being well distributed among the other senses. Such results show the existence of individual differences, but do not confirm the assertion that some people use one type of imagery only.

The Measurement of Retention. The effects of retention are shown in three principal ways. First, material is known to have been retained if it can be *reproduced or recalled* upon appropriate stimulation. Second, retention can be detected by *recognition*, as when events are recognized as having been met before or as being correct, even when they could not have been reproduced. Third, retention has effects upon *relearning*. An individual who has studied trigonometry a long time ago may be unable to recall a single fact of the subject, but he probably will be able to relearn it with less than the original amount of effort, indicating that some retention has persisted.

The most dependable information about remembering is obtained by experiments that use the three evidences of retention just described. Subjects who have learned a list of words may be required to reproduce them after the passage of various intervals of time. This is recall or reproduction memory. If learning has been less thorough, the recognition method of testing may be used to advantage. The words of the learned list are mixed with an equal number that were not seen before, and the subject must choose or recognize the proper words. A third method of research, considered more precise than either of the others, uses relearning and is known as the *saving method*. The material is learned to some arbitrary degree of perfection, such as two perfect reproductions. At a later time the same material is relearned to the same degree as before. The amount of retention is the difference between the effort required for the first and second learnings, usually expressed as a percentage. Thus if a list of words is learned originally in 10 repetitions and relearned the next day in 4 repetitions, the "saving" is 6 trials and the retention is 60 per cent.

The Effect of Time upon Retention. The most common observation about retention is that recall becomes increasingly difficult or inaccurate as time passes. Yesterday is remembered fairly well, but few persons can tell what they had for dinner on Monday of the week before last, unless some special occasion gave intensity to the original impression. The effect of

time upon retention was one of the problems investigated by Ebbinghaus in his pioneer studies. Using the saving method, which he devised, Ebbinghaus found the results shown in Fig. 97. To control the difficulty of the material he used nonsense syllables, which are word-like forms without meaning such as *tov, daz, nup,* and *jid.* The retention was found to be 58 per cent at the end of twenty minutes, less than 44 per cent after one hour, and 21 per cent at the end of thirty days.

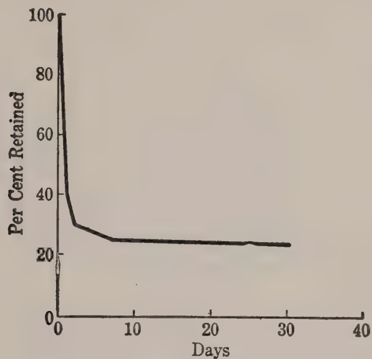


FIG. 97. A Curve of Forgetting.

The distance of the curve above the base line indicates the amount retained at various intervals of time after learning. (After Ebbinghaus.)

Many other experimenters have repeated this study, usually finding curves of the same general form, but with a drop not quite as steep as that of the first research. Ebbinghaus used material of the greatest difficulty and learned his lists, in various experiments, only to the point of one or two successful repetitions. These facts account for the rapidity of forgetting found by him. Retention is better if the material is connected and meaningful, if it is practiced more times, and if it is learned by efficient methods. All studies, however, find that the greatest rate of forgetting occurs in the hours immediately following learning, and that there is a negative acceleration of the process thereafter.

That forgetting occurs with time is a generally dependable fact, but serious doubt has been raised as to whether mere

time is the ultimate explanation of the process. The effects of intervening activities, and the pleasantness or unpleasantness of the associations, seem more basically significant.

The Effect of Intervening Activities. Certain experiments indicate that forgetting is caused by the interference set up by subsequent activities which act upon the material that has been learned. This phenomenon is called *retroactive inhibition.* The simplest evidence concerning retroactive inhibition comes from an experiment involving the comparison of two groups of subjects, the outline of which is as follows:

Order of Procedure	First Group	Second Group
First:	Memorizes material "A," such as vocabulary in a foreign language.	Memorizes material "A," such as vocabulary in a foreign language.
Second:	Further mental work "B," as in reciting other words.	Rest.
Third:	Tested in recall of material "A."	Tested in recall of material "A."

Both groups learn the material at the same time and attempt to recall it at the same time, but the interval between acquiring and recalling is occupied differently. In the experiment described, the second group excels the first in the retention of material "A." Further experiments show that the degree of forgetting or inhibition varies directly with the similarity of materials "A" and "B." A very similar intervening task causes much forgetting, whereas a very different one has little effect.

The findings concerning retroactive inhibition explain many everyday observations. In constructing a school schedule it is better to have mathematics followed by history than by physics, since the former is less similar. A game of tennis or a round of golf creates little interference with study, whereas other study may inhibit retention. This also explains the value of spaced learning, which has already been described. Too long a period of study may interfere with its own efficiency;

the same amount of time spread out and punctuated by different activities avoids the adverse effect.

Material is often retained better when it is studied just before going to sleep, as common observation has shown. Several experiments have measured retention over intervals of sleeping and waking. In one typical experiment by Van Ormer (1932), subjects learned lists of nonsense syllables

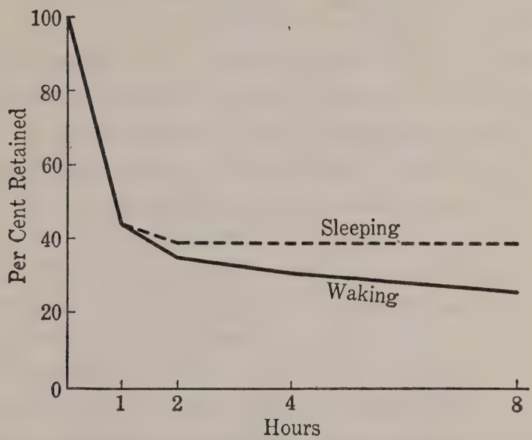


FIG. 98. Retention During Waking and Sleeping.

The solid line shows the curve of retention after one, two, four, and eight hours of normal waking activity. The dotted line shows the retention over periods of sleep. (After Van Ormer.)

at about 11 P.M. and immediately went to sleep. After intervals of one, two, four, or eight hours they were awakened and their retention was tested by the savings method. For comparison, other lists were learned at 9 A.M., and retention was tested after one to eight hours of normal waking activity. The results (Fig. 98) show the usual curve of forgetting for the waking periods. The curve of retention during sleep shows superiority at all but the one-hour interval. Indeed, the data show practically no forgetting during the period between the second and the eighth hour of sleep. Since some interference inevitably results from the acts of going to sleep and of

getting awake again, it is entirely possible that no forgetting at all occurs while one is really asleep for any interval.

The experiments on retroactive inhibition and on retention during sleep make it doubtful that the mere passage of time causes forgetting. Probably *all* forgetting is due to interference. During normal life it is impossible to avoid other activities that inhibit what has been learned. Time is a significant factor in forgetting only because of the interference set up by the experiences that fill the time.

Pleasantness and Unpleasantness in Retention. Another factor that affects retention is the pleasantness or unpleasantness of the material that is to be remembered. A typical experiment on this problem was conducted by Meltzer (1930). A group of college students was asked to record all the experiences that each could remember from an immediately preceding Christmas vacation. Each experience was marked as pleasant or unpleasant. Six weeks later, without warning that a second recall would be demanded, the group was again called upon to list the experiences. Of the pleasant memories 53 per cent were retained, while only 40 per cent of the unpleasant could be recalled. Statistical analysis indicates that this difference is significant.

The tendency to remember the pleasant is frequently observed in common experience. To most persons, childhood seems a joyous period of life because its pleasures are remembered better than its sorrows or humiliations. After a long trip, the pleasant occurrences stand out and the troubles may be forgotten. To some extent this phenomenon is due to exercise and review. Pleasant events are often told to others or reviewed in revery, while a painful memory is inhibited by turning to other occupations as soon as it is recalled. After a time an individual becomes skillful in *not-recalling* some things, after which he can remember them only with difficulty. There are some apparent exceptions to this principle. If an event is well acquired it may be retained in spite of an unpleasant connotation. But some extremely intense experiences,

especially if they involve fear, often are forgotten by the process of emotional inhibition. Some persons remember unpleasant events better than do others. It is often suspected that these pessimists obtain a sort of satisfaction from brooding over their miseries, substituting self-sympathy for a motivated need to receive the attention and sympathy of others.

The forgetting of an unpleasant or humiliating experience is sometimes called *repression*. It must be remembered, however, that the forgotten material is not repressed into any particular place "in the mind," but is merely inhibited. That some traces of retention persist for a long time in such cases can often be demonstrated. If, by talking and reassurance, a person comes no longer to fear a past repressed experience, the inhibition is removed and he can remember it fully. Extreme cases sometimes combine the forgetting of the unpleasant with retroactive inhibition. After some particularly terrible experience, an individual may be found to inhibit the recall of all his past life. This condition is known as *amnesia*, or loss of memory. A number of cases occurred during the war of 1914-1918, and others are found in civilian life from time to time. When amnesic persons are brought back into contact with their familiar surroundings they can usually be reeducated to recall their past lives again. Amnesia may also be caused by physical injury of the nervous system, especially of the cerebral cortex.

The Improvement of Remembering

Everyone values his ability to acquire, retain, and recall, and most persons would like to improve the efficiency of these functions. Of the various procedures that have been relied upon to "improve the memory," some are utterly ineffective and others have very limited value. By following other suggestions, however, it is possible to improve the function of remembering, but not without much effort.

"Mental Discipline" not Valid. The oldest fallacy about remembering is the belief that memory, "like a muscle," is im-

proved by practice. This tradition is a part of the doctrine of "mental discipline," which holds that the mind is trained generally by any sort of mental work. Although this doctrine has long been believed, experiments have shown that mental discipline is not dependable.

The disciplinary value of memorizing may be measured by an experiment. Two groups of subjects are tested in their ability to memorize several kinds of material. One group is then given extensive practice in memorizing some *other* variety of material, while the other group does nothing. Finally, the memorizing ability of both groups is again tested, with the same kinds of materials as in the first test. By this technique, for example, the effect of twenty hours of practice in memorizing poetry upon the ability to learn and remember biographical stories can be measured. The results of these experiments are decisively negative. Practice with poetry often slightly improves the ability to learn more poetry, but it has a neutral or even adverse effect on the ability to memorize a different sort of material, such as meaningful prose. The net effect of a large amount of memorizing of one material upon the ability to memorize *all* other kinds of materials is approximately zero. Memory training, then, cannot be achieved just by the labor of memorizing.

A broader study of mental discipline directed by Thorndike (1927) investigated the belief that some school subjects "train the mind" more than others. Tests of a large number of mental functions were given at the beginning and end of a school year, and the gains made by pupils who had studied various subjects were compared. This research showed that the differences between the various subjects were small. Moreover, the traditionally "disciplinary" studies did not justify their reputation. Latin and geometry were of indifferent value in producing gains in mental abilities; some untraditional subjects, such as accounting and business arithmetic, excelled them. In general, the mere performance of difficult work does not "train the mind." School subjects are of value only when they impart

useful knowledge or teach the students improved methods of attacking other real problems.

Mnemonic Systems. A system for improving remembering that has some value for limited applications is the *mnemonic device.* These systems are usually sold commercially, and excessive claims of their usefulness are made by the vendors.

One type of mnemonic system substitutes meaningful material for meaningless, which is not a bad principle in itself. Numbers, for example, are turned into letters or words that have a logical association with the significance of the number. First, certain letters that can stand for numbers must be memorized. The numeral "1," for example, might be *l* or *i* or *t*, all long thin letters like the "1" itself. Suppose, having learned the system, one wishes to remember that the telephone number of the Alpha Beta fraternity is 1847. Alpha suggests "first" or "early," and we find that 1-8-4-7 can be turned into l-a-r-k, which can be remembered as "the early bird." In recalling, the person starts with Alpha, which leads to "early bird" and in turn to "lark," which is deciphered as 1847. There is no doubt that such a system will work, but the amount of labor and ingenuity required might better be spent in more profitable pursuits.

Another mnemonic device makes the user memorize a long list of words such as *bag—table—hat—wagon*, etc. To remember a grocery order, he now imagines putting the peas in the bag, the beef on the table, the oranges in his hat, and a load of flour on the wagon. By visualizing these imaginary manipulations and repeating them, he connects the real task with his artificial list of words. At the store, he says over his memorized list, which serves to remind him of his purchases. One wonders if a less elaborate procedure would not get results just as effectively.

Advertised systems for "improving one's memory" usually consist of appeals to mental discipline and of mnemonic systems. Although the latter have some slight utility, a much higher price is charged than they are worth.

Learning How to Remember. It is possible to improve the ability to remember in some degree by learning how to use efficient methods for acquiring and recalling. Experiments show that training in *methods* of remembering yields far better results than does mere practice in memorizing. Woodrow (1927) showed that 177 minutes of pure practice resulted in a net gain of only one per cent on six tests of memory. Another group, however, spent its 177 minutes half in listening to lectures on how to memorize and the other half in applying these principles. This group made a gain of 32 per cent. The first conclusion confirms the results of the studies of mental discipline. The second finding shows the value of learning how to do the task efficiently. The principles of effective memorizing taught by Woodrow to his experimental group included:

1. Learning by wholes.
2. The use of self-recitation.
3. The use of rhythm and grouping.
4. Attention to meaning.
5. Alertness and concentration.
6. The use of associative clues for recall.

None of these are occult principles, and all of them have been described in this chapter. A careful application of these methods may yield large dividends in the improved efficiency of the functions of acquiring and recalling.

Chapter XIII

THINKING

Thinking, or reasoning, is a problem-solving process. It is undoubtedly the most efficient of the various methods that human beings use in the attempt to overcome their difficulties. A preliminary view of the nature of thinking can be obtained by contrasting two approaches to the same problem. As an illustration, let us consider two chess players each of whom is engaged in trying to solve some standard chess problem.

One of the players may try to find the solution by manipulating the pieces on the chessboard, moving them in succession until he sees that his attack is unsuccessful. Then he returns the chessmen to their original positions and tries a new sequence of operations. After several such efforts he eventually hits upon the combination of moves that gives the desired result, and his task is completed. This is problem-solving by motor or manual manipulation.

The second chess player may resort to a quite different behavior in order to attain the same end. He sits before the board and surveys the situation. Occasionally he may scowl, emit a sigh or a grunt, turn his head from side to side, or make incipient gestures. Then, perhaps after many minutes of such contemplative activity, he touches the pieces for the first time and moves them rapidly and precisely to their correct places. An observer can see that the second player has not been idle. He has been active, but in a rather different way from that of the first player. He has been "thinking," and by this process has arrived at a solution as good as that which he could have attained by trying all the moves overtly.

Thinking, then, is a process of problem-solving that differs in many ways from the manual trial and error that searches somewhat blindly for a solution. The purpose of this chapter is to investigate the nature of thinking: to see what kind of a process it is, and to find out what goes on within an individual who is engaging in it. Thinking is a very complicated human activity, but not a rare or mysterious one. The thinking done by a genius may produce mathematical or scientific theories, or great works of literature, music, or art. Yet every person thinks daily, as when he orders a dinner in a restaurant, plans the route for an automobile trip, or is confronted by a host of other commonplace situations that call for a decision.

Problem-solving

An analysis of the cruder forms of problem-solving provides an appropriate background for the study of thinking. To any organism, a problem is a situation that calls for motivated behavior, but which cannot be solved by the sole use of previously established habits. All animals solve problems, from amoeba to man, and all use fundamentally similar methods in doing so. Experiments dealing with problem-solving by lower animals show the essential characteristics of the process clearly, because the problems solved and the methods used are somewhat simpler than in the case of man.

Explicit Problem-solving. One of the earliest experimental studies of animal behavior, by C. Lloyd Morgan, dealt with the solution of a problem by a dog. Morgan's dog had learned to retrieve his master's cane when it was thrown to him. In one observation, Morgan threw the cane over a hedge in which there was an opening only large enough for the dog to run through. The dog went through the gap in the hedge, picked up the cane by the middle as was his habit, and tried to return the same way. The projecting cane, however, prevented his passage through the narrow hole. After a few vigorous but futile shoves, the dog retreated and dropped the cane, only to repeat the performance soon afterward and to experience another failure. After several such trials the

dog, *by chance,* happened to seize the cane near one end instead of at its center, and got through with the cane trailing along his side.

During the past forty years many observations of problem-solving by animals have been made in psychological laboratories under more carefully controlled conditions. Some of these experiments have been described in Chapter V, and need not be repeated here.[1] In essentials, most of the more precise experiments confirm the general picture given by Morgan's observation. Most of the problems met by lower animals are attacked explicitly and overtly, that is, by the direct manipulation of the physical materials provided by the problem. Explicit problem-solving is the *trial and error* process that has been seen in many other instances of behavior. In Chapter V, which dealt with the learning process, the emphasis was placed on the progressive changes in the animal's activities that occur when he solves a problem *repeatedly*. A different analysis is now called for, with the chief attention on the way that an animal solves a problem *for the first time*. This is a practical approach, for in real life many problems are met once, solved, and never encountered again.

The first requirement of the problem-solving process is the existence of some *motive*, need, or urge to activity. Morgan's dog was motivated to bring back the cane in order to secure approval. In many animal experiments hunger is used as the motive. Second, the animal's motivated behavior is subject to *thwarting* by some circumstance that prevents the immediate completion of the act. Third, the organism engages in *varied responses*, or "trial and error," until, fourth, some *solution* is hit upon which fulfills the original need and completes the sequence of activity. This analysis—(1) motive, (2) thwarting, (3) varied responses, and (4) solution—applies broadly to the more complicated processes of reasoning, as well as to the simpler explicit forms of problem-solving.

The Beginnings of Reasoning. Manipulative trial and error is the most common form of problem-solving, but true rea-

[1] See pp. 102-110.

soning shows some further characteristics of great importance. For one thing, explicit problem-solving typically proceeds directly toward the goal. Then again, variations in behavior result chiefly from changed external stimuli. And finally, each new situation is a fresh problem that is attacked with little aid from past experience. Reasoning differs with respect to each of the above three features. In human reasoning, an *indirect method* is often used to attain the goal, *symbolic stimuli* or "inner" cues originating from the individual are used in place of external stimuli, and, notably, acts learned at different times and places are *combined* or put together appropriately without further specific practice. These three earmarks of reasoning are also found in the behavior of lower animals under some circumstances. This fact is not surprising, since man and the other animals form a continuous biological series. Men sometimes solve problems by the blind fumbling that is characteristic of animals, while animals show, in some slight degree, behavior that must be regarded as reasoned.

One of the first and simplest evidences of something higher than random trial and error is found in the experiments on *roundabout* or *"detour" behavior* reported by Köhler (1925). A dog was released into a narrow alley, one end of which was closed by a fence (Fig. 99). When food was placed on the

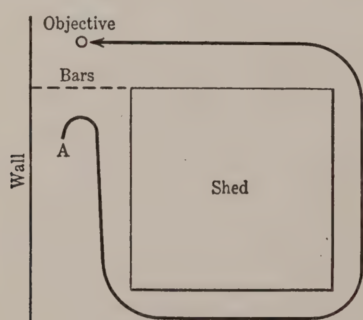


FIG. 99. Detour Behavior of a Dog.

Starting at *A*, the dog turned immediately and ran an uninterrupted course to the objective. (Modified from W. Köhler, *The Mentality of Apes*, Harcourt, Brace.)

opposite side of the fence, the animal hesitated only a moment, then turned round completely and ran in a smooth and uninterrupted curve around the obstruction to secure the food. Apes did even better than the dog, and could take a complicated roundabout course to secure food that had been tossed out of a window to a point they could not see. Hens, on the other hand, were generally unsuccessful in this problem. They ran at the bars, then away from them, and then parallel to the obstruction (Fig. 100), as if impelled mechanically by two

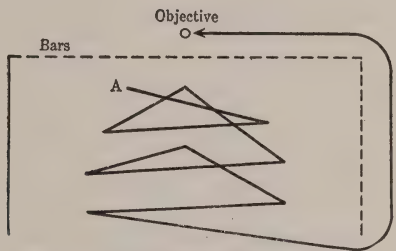


FIG. 100. Detour Behavior of a Hen.

Starting at *A*, the hen ran back and forth behind the bars, and reached the objective only by trial and error. (From W. Köhler, *The Mentality of Apes*, Harcourt, Brace.)

forces which made them go toward the food but away from the barrier. Only if chance brought them to a point from which the roundabout way was short did the hens succeed at all. The successful roundabout behavior of the dogs and apes is significantly suggestive of an important aspect of reasoning. When the animal turns his back on a desirable objective as a means of reaching it, he must carry along some representation of the goal. Some rudimentary kind of "idea" or "thought" of his objective keeps him going when he cannot see the goal itself.

Still clearer evidence of the existence of symbolic or "thoughtful" behavior in lower animals comes from experiments with the *alternation problem*. An animal is placed at the entrance of the apparatus (Fig. 101) and is trained by food rewards to make a right turn, and then, upon approach-

ing the choice point for a second time, to make a left turn. Rats, sheep, and raccoons succeeeded in mastering this problem, taking alternately the R and L turns. A more difficult task that can be presented with the same apparatus is the *double alternation problem*, in which the animal must go twice to the right and then twice to the left, that is, in the RRLL order. Rats could not learn this task, but it has been acquired by cats, dogs, raccoons, and monkeys with varying degrees of

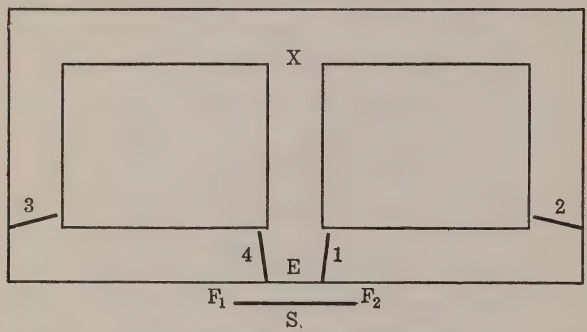


FIG. 101. The Alternation Maze.

Starting at the entrance *E*, the animal goes down the central alley to the choice point *X*. It is trained to make turns at *X* in the order right, right, left, left. The doors *1, 2, 3,* and *4* are closed behind the cat to prevent his retracing the alleys after having made a correct turn. Correct responses are rewarded by food at the points F_1 and F_2. The experimenter observes the animal's behavior from behind the screen *S*. (From H. W. Karn, *J. Compar. Psychol.,* 26:203, 1938.)

effort and mastery. The double alternation problem gives especially striking evidence of the use of symbolic or inner cues. On the second run the animal, having just run R, faces the choice point and must turn R again. But on the third run, also having just run R, it faces the identical external situation, but must now turn L. The animal responds differently on these two trials not only to the same external stimulus but also to identical "traces" of immediately preceding behavior. The stimulus that determines its success is therefore inner or symbolic. The animal must have some rudiments of the ability to *count*. It thus employs, to a degree, the same kind of cue that in more elaborate form is necessary for human reasoning.

A third sign of incipient reasoning in lower animals is the appropriate combining of separately learned reactions into a new total act. This has been shown by several studies, among which a certain maze experiment by Maier may be chosen as an example. Maier trained rats in the task of running an open

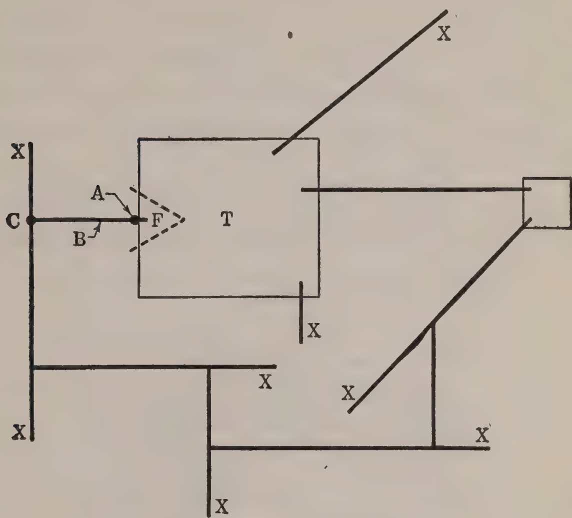


FIG. 102. Maier's Elevated Maze.

The maze is elevated about two feet from the ground and consists of narrow wood strips supported by iron rods. First, the rat was placed on table *T* and was permitted to learn the indirect maze route to the food *F*, to which the direct route was barred by a wire screen. Second, the rat was taught to climb from the ground to the food up a support rod at *A*. In the critical trial, the rat was placed at *T*, and section *B* of the maze was removed. It ran to *C*, climbed down the support rod at that point, and up rod *A* to the food. Blind alleys in the maze are marked *X*. (From N. R. F. Maier, *Intelligence of White Rats,* motion picture film.)

or elevated maze of which all parts were visible. Also he released the rats on the ground near the support A (Fig. 102) and let them learn to climb up this support to reach the food. In the critical trial, section B of the maze was removed. After some aimless wandering in the intact part of the maze, some rats went down a support rod across the ground, and *promptly* ran across the ground to rod A, which they climbed to reach

the food successfully. The rats had never used this path before but they combined the two previously learned acts—running the maze and reaching the food from the ground—into a new unit of adaptive behavior. This sudden act of perception or "insight" that solves a problem is emphasized by the Gestalt interpretation of learning which was described in Chapter V. In this particular experiment it is interesting to note that "detour" behavior also appears, since the rat must turn his back on the goal in order to run the maze. Maier interprets his findings as evidence of "intelligence" or "reasoning" in rats.

Experiments in Human Problem-solving. The classic experiments on problem-solving by human adults were performed by

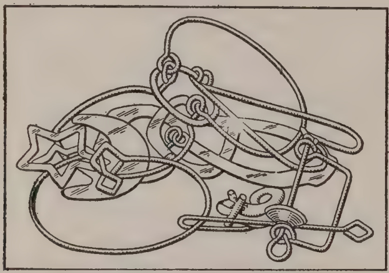


FIG. 103. Mechanical Puzzles.

These are several of the mechanical puzzles used by Ruger (1910) in his experiments on problem-solving. (Courtesy of C. H. Stoelting Co.)

Ruger in 1910. *Mechanical puzzles* (Fig. 103) were selected as material similar to the problem boxes used with lower animals. Observations were made of subjects' methods of work, of their remarks while solving the puzzle and their comments after each solution, as well as of the time taken to solve the puzzle on each trial. Typically, the subject manipulated the puzzle in a rather random fashion at first, trying one means after another to separate the pieces. The first solution usually came about accidentally, and without understanding on the part of the subject. Following each solution, the puzzle was immediately put together by the experimenter, and the sub-

ject was made to try again. After a number of trials, the subject succeeded in making some *analysis* of the solution, and the time needed to take the puzzle apart decreased thereafter. Ruger found that the analysis came about *after* a solution, and not before. The first crude understanding was *place analysis*, by which the subject perceived the part of the puzzle that must be manipulated. Place analysis often occurred after the first chance solution and brought about some decrease in time. After several more trials, the subject typically achieved a *detail analysis*, or a perception of the exact movements necessary for the solution. One striking conclusion from this experiment was the *sudden* appearance of analysis. After blindly fumbling with the puzzle for several trials, the subject would "see the light" quite abruptly, and carry through the solution with speed and certainty thereafter. The two factors that led to the efficient solution of the puzzles were (1) *variability* of attack and willingness to try another method after one had proved fruitless, and (2) *insight* into the nature of the task, or conscious and symbolic analysis of its difficulties.

Another experiment that reveals the nature of human problem-solving and permits its comparison with animal behavior, is the *multiple choice experiment* devised by Yerkes. The apparatus consists of a box from which any of twelve keys may be projected toward the subject (Fig. 104). Small lamps visible to the experimenter show which key the subject has depressed; touching the "correct" key causes a buzzer to sound, informing the subject of his success. In the experiment, a problem consists of a constant generalization running through a series of trials. For example, the generalization may be "the middle key," and this key is always the "correct" one of any assortment of keys that may be presented. The subject knows only that one key is correct. He must discover which one, and, in a series of trials, must discover the underlying generalization. On the first trial of any experiment, the subject must resort to random trial and error. Upon discovering the correct

key, he may make an *hypothesis* or tentative generalization to try on subsequent trials. This generalization may prove to be

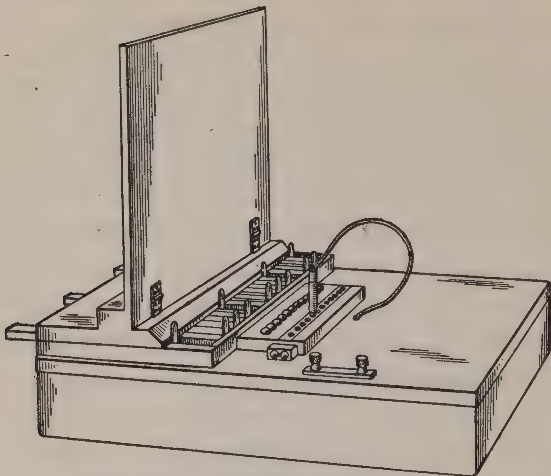


FIG. 104. Yerkes' Multiple Choice Apparatus.

The task presented by this apparatus is to discover the generalization that underlies the selection of the "right" key in a series of settings. See the text for further description. (Courtesy of C. H. Stoelting Co.)

true, or it may be false and have to be discarded. A sample experiment may proceed as follows. The "setting" shows the keys presented at each trial, the "responses" indicate the order in which these keys were pressed by the subject, the last one being "correct" in each instance. The most important data are the subject's observations.

Trial	Setting	Responses	Subject's Observations
1	4–5–6–7–8	4	"This is easy. It's the left-hand key."
2	1–3–5–7	1, 3, 5, 7	"No, it can't be the left one, but it seems to be on an end."
3	2–4–6–8–10–12	12, 2	"It changes from one end to the other."
4	5–6–7–8–9	9	"It is alternately the left- and right-hand keys."

Among the problems that have been used in the multiple choice

experiment are (1) first at left end; (2) middle; (3) third from right end; (4) alternately left end and right end; (5) one place to left of middle; (6) alternately to left of middle and to right of it. Human adults can succeed in all these problems, but they find the last ones very difficult. Lower animals have been tested in the same situation by using a series of food boxes in place of keys. Beyond learning to choose one end, or alternate ends, rats, cats, and pigs made no appreciable progress. Some monkeys mastered certain more difficult problems when presented with one series of settings, but fell into many errors when the same generalization was presented in new settings. Spence (1939) found that chimpanzees could learn to solve problems involving the choice of the end, the next to the end, and the middle, of a series of boxes.

The multiple choice experiment shows the process of *making and testing an hypothesis* in problem-solving. Human beings usually formulate their hypothesis in *words*. They say "first at the right" either aloud or inwardly to themselves. In some cases, however, they may use other signs and symbols such as gestures, nods of the head, eye fixations upon the correct key, and similar postures or clues. As was found also in the experiments with mechanical puzzles, the successful hypothesis may come suddenly after an apparently unproductive period of fumbling.

The general analysis of problem-solving that was made earlier in this chapter may now be enlarged to include the beginnings of reasoning, as found in the experiments just described. A problem implies a *thwarted motive*, an act that the individual wants to perform that he cannot do immediately. His *varied responses* aroused by the problem may involve overt muscular movements, but attain greater efficiency when words or other symbols are used. An analysis of the problem and the formulation of hypotheses or possible solutions also add to the speed and scope of problem-solving. Furthermore, the varied responses are not reactions to the present situation alone, but may include responses to recalled past experiences and even to

new combinations of such experiences. The *solution* of the problem may be tentatively accepted at first, and then verified by additional trials and observations. The higher types of problem-solving add something to crude animal trial and error, but follow the same general pattern.

Reasoning

Implicit Problem-solving. Reasoning differs only in degree from other forms of problem-solving. When a person reasons he does not have to make any ordinarily observable muscular movements or utter any vocalizations that can be heard by others. He may sit quietly in his chair with his eyes closed, and finally emerge with the answer to a problem. Of course, reasoning is often combined with motor activity in real and useful pursuits. It is not always an armchair occupation, but it *may* be such on occasion.

The essential features of reasoning are revealed by examining an instance in which it is used in everyday life. A visitor at an airport saw something he had never noticed before, a long strip of black substance, apparently rubber, along the front edge of each wing of a transport plane. What was it for? At once the thought occurred to him that it was some sort of a "bumper" designed to cushion a blow and prevent damage to the wing. This was rejected immediately, since such a strip would be no appreciable protection in the event of a crash, and would scarcely be needed to safeguard the plane against careless handling in the hangar. Perhaps it was an insulating sheath covering the wires that go to the wing lights. But observation showed that it did not always terminate at the lights, and besides, was too bulky for this purpose. The visitor then surmised that this rubber strip might cover a movable mechanism for changing the tilt of the edge of the wing, but this purpose seemed contrary to any of his past observations concerning airplane design. The last thought, however, provided another clue. The rubber strip could move! He had heard that there was a device to prevent the formation of ice on airplane wings.

Furthermore, the observed sheath could serve this purpose. If the rubber were moved slightly while the plane was in flight, it would cause the ice to crack off as fast as it formed. This last supposition seemed to be the most likely one, and the visitor was satisfied. Later, lacking a more direct way to confirm his opinion, he inquired of an airport official and was told that the rubber edge, rhythmically expanded and deflated by puffs of compressed air, was indeed a protection against ice.

Many similar observations of thinking can be gathered from anyone's experiences. Problems and examination questions in school, perplexities in professional and business life, and unfamiliar events in the home or on the street call forth this process. An individual often reasons out answers by implicit problem-solving when he meets questions such as these: What is it? How does it work? What causes that? How can I get there?

Reasoning Analyzed as a Whole. An instance of thinking, such as that just described, may be analyzed according to the general scheme proposed by Dewey (1910). Reasoning may be regarded as a series of steps that follow one another in an orderly way. These are: (1) a problem or difficulty, (2) the observation or recall of significant facts about the problem, (3) the suggestion of possible solutions or explanations, (4) the criticism of these suggestions in the light of further observations or deductions, and (5) the acceptance or rejection of a proposed solution.

The beginning of an act of reasoning is always a *problem.* Unless something disturbs the individual or makes him want to know an answer, no real thinking can occur. It does no good to tell a person to "think" unless he has something to think about. Necessity is the start of the thinking process. Some people do more thinking than others because they have established habits of greater curiosity. To such persons a situation may call for an answer or explanation, whereas others do not notice the issue or are content to remain ignorant.

The second stage of thinking consists in making *observations*

or recalls that define the problem and state the circumstances surrounding it. In simpler cases all the useful facts may be observed at the moment that the problem is perceived, while in other instances the observations may be prolonged and detailed. Again, all necessary facts may be present for immediate observation, or they may have to be recalled by processes of remembering. In "armchair" reasoning, which is perhaps the "purest" although not necessarily the most useful kind of thinking, all the observations may have been made in the past and are represented by symbols and recollections.

Third, the thinker begins to make *suggestions* that might lead to the solution of his problem. These are hypotheses or tentative answers one or more of which may stand the test of further analysis, while others will be discarded. It is important for a thinker to have a good supply of possible solutions that he can propose. Other things being equal, the more suggestions he can make, the more likely he is to find a good one.

Next, each suggestion is subjected to *criticism* as it is proposed. The criticisms may arise from the observation of further immediately perceptible facts, or from recalled facts that were observed in the past. Criticism by observation or recall is of less consequence, however, than criticism by deduction and inference. *If* the suggestion is true, what must follow? What other conclusions must be drawn? If these inferred consequences of the hypothesis are known to be true, or if they agree with past observations, then the suggestion is strengthened. If the deductions from an hypothesis are absurd, the suggestion is seriously impaired and usually must be rejected. In the usual course of ordinary thinking each suggestion is weighed as soon as it is discovered, and another hypothesis is proposed only after the preceding one has been discarded. It might be desirable to tabulate all the possible explanations before evaluating any of them, but this is done only in very formal reasoning, as in certain theorems of geometry.

The fifth stage of the thinking process represents the outcome, a suggestion so weighed and accepted that it has become

a *conclusion*. Relatively few conclusions become final without further observation or experiment, however, no matter how attractive they may have seemed when first conceived. Many outcomes of thinking are verified by action, as when the thinker puts his conclusion to the test of a concrete application. Other problems cannot be judged in this way, but must be subjected to further reflective thinking. Perhaps lowest in the scale is the test of authority, which was used by our airport visitor when he made inquiry of a better-informed person.

Introspective Experiments in Thinking. A gross analysis of a reasoning process as a whole is illuminating, but it still leaves unanswered some of the most pertinent questions about thinking. What goes on when the individual thinks of an hypothesis? What kind of an act is his criticizing and accepting or rejecting a proposed solution? Some further information on these questions may be gathered from experiments on thinking.

Shortly after 1900 several groups of psychologists in Germany, France, and America independently began a certain type of research on thinking. The method used seems obvious, and it is remarkable that it had not been tried before. An observer or subject, trained and experienced in giving introspections or reports of his conscious processes, was presented with a problem. A task was chosen that was not so easy that an immediate answer could be given, or so hard as to take too long to solve. After giving the answer, the observer reported what he had experienced while solving the problem. It must be emphasized that the report consisted of the observer's *experiences*, of his consciousness, not merely of the steps taken to solve the problem.

Some of the more common elements of conscious thought may be mentioned first. Almost all observers found that *images*[2] were present during thinking, and were employed to symbolize, or "stand for," things not present to the senses. Thus in thinking about the meaning of a proverb, the subject had a visual image of a thing to which the proverb referred,

[2] See p. 332.

or an auditory image of the sound of one of its words. Second, present *sensations*, especially of incipient movements, were often reported as significant elements of conscious content during thought. William James stated, for example, that his thought of the word "but" consisted of a suspended, baffled, motor attitude. In this instance the conscious element is kinesthetic sensation, arising from subtle but actual muscle movements. A third element commonly found was *words*. The thinker often talked to himself, either fully or in an abbreviated way. Sometimes the words were heard as auditory images of his own voice, more often they were expressed as slight movements of the larynx, throat, and lips.

The discovery of images, sensations, and words during thought processes caused no surprise, for older classical views had held that *all* thinking was expressed in these elements. The "thought experiments" found other content in thoughtful experience, however. Of these other experiences, the most important was characterized only by the negative phrase, *imageless thought*. Almost all observers reported at times that they had a clear consciousness of meaning *without* any words, images, or sensations. Typically, the meaning or answer of a problem came suddenly and clearly. Only *after* the meaning was sensed as a whole did the observer formulate the words in which to express it. "Imageless thought" aroused great controversy, some writers claiming that the sensory content of the thought was not absent, but was merely unobserved because of inadequacies of procedure.

Two kinds of "imageless thought" that were described in these early experiments contribute to an understanding of thinking as a whole. One group of experimenters described certain introspective states as *conscious attitudes*. These included feelings of certainty, doubt, hesitation, expectancy, and inspiration that were definitely conscious, but did not consist of images, sensations, or words. These were very important in thinking, for such an act as "criticizing an hypothesis" was often performed by such a conscious attitude, rather than by a

word or an image. Another type of "imageless thought" was described as a *determining tendency*. For example, if the task assigned was to give the opposites of words, the attention and consciousness of the individual were directed to the words themselves, while the task that determined the response lurked far in the background. Still, under the influence of the determining tendency, the subject gave opposites rather than synonyms or other relationships.

The experiments on "imageless thought" were chiefly of value in breaking down the older theory that all thinking is done by the use of logical sequences of words and images. It became apparent that other responses than words or images can symbolize the meanings that are manipulated during an act of thought.

Motor Aspects of Thinking. The older introspective experiments on the thought processes emphasized the *sensory* content of reasoning, that is, the images and actual sensations that were present in consciousness. It was not long before a *motor theory* was proposed as an alternative, which held that the "mental" elements of thinking consisted in slight, tentative, or incipient movements of groups of muscles. According to this view, an idea might consist in a movement rather than in an image.

Experimental studies soon were made to test the motor theories of thinking. Because the notion that thinking consists of talking to oneself had been so prevalent, investigations of incipient movements of the vocal mechanisms have been of special interest. The first experiments used relatively crude methods for recording movements, such as tambours placed on the throat and levers attached to the tongue. A subject was required to say a word, and then to think that word silently. In general, slight movements were found to take place while he was thinking of the word. These often resembled the movements used to say the word aloud, although they were of smaller extent or strength. One valuable observation was that a slight movement might occur during thought without the

subject being aware of it. This points to a criticism of the introspective experiments. For an introspective observer to report that he experienced no sensations of movement does not prove that no movements occurred. Instead, they may have been so slight that he did not become aware of them. The earlier experiments on incipient muscle movements were not fully satisfactory because of the crudeness of the instruments used for measuring and recording them.

More recently, delicate methods for detecting movements by electrical methods have been perfected. Electrodes are placed on the skin or in a muscle which pick up the minute *action currents* that are generated whenever the muscle is moved. The currents are amplified to an intensity that can be recorded. One of the most extensive series of experiments using this method has been performed by Jacobson. He found that in solving concrete or abstract problems, very small movements of the tongue occurred that resembled those made during actual speech. In simpler tests, he found that when a relaxed subject was instructed to think or imagine a certain movement such as lifting the arm, specific action currents could be detected in the arm muscle. Furthermore, it was impossible to think of a motor act without making microscopic movements of the muscles involved in that act. When a subject with an amputated leg was instructed to think of moving the lost limb, he could do so only hazily, and his thought was accompanied by actions of other muscles which apparently substituted for the amputated ones. When told to imagine the Eiffel Tower, a subject made incipient movements of the eye muscles identical in pattern with those made when actually elevating the eyes.

Similar experiments were conducted on deaf-mutes by L. W. Max. These deaf-mutes used sign language, and might be expected to "think with their fingers" to the same extent that normal persons think by means of inner speech. Max found that the onset of dreams in sleeping deaf-mutes was accompanied by action currents in the fingers which were absent

from normal subjects under like conditions. Abstract thinking, in the form of arithmetical and logical problems, elicited action currents in the hands in 84 per cent of instances in the deaf-mute subjects, but in only 31 per cent of instances in hearing subjects. These results confirm the conclusion that movements occur during thinking, and that they may not rise above the threshold of consciousness and can be measured only by electrical methods.

The Nature of Thought. The evidence from various sources has now been gathered together, and a more comprehensive statement can be made concerning the nature of an act of thinking. A gross analysis of the thinking process has shown that it consists of the suggestion of hypotheses which are criticized and accepted or rejected. In overt problem-solving, as in the solution of a mechanical puzzle, the hypotheses are the "trials" and are carried out by obvious manual manipulations.

In reasoning, the hypotheses are meanings of various sorts, arising from immediate perception or from memory. These meanings are symbolized by the responses that the individual makes while he is thinking. The responses employed in reasoning are implicit in that they are hard for an outside observer to detect. They are symbolic, since they stand for something beyond themselves. These responses may be sensations, images, language sequences, or very slight incipient movements. They differ from the responses made in overt problem-solving only in degree. In muscular problem-solving, the responses are large muscle movements. In thinking, the responses are images or slight muscle movements, but they are responses none the less. According to this view, persons think not only with their brains but with their entire bodies. The nervous system has a central rôle in thinking because it connects and integrates all other parts of the organism, but the sense organs and muscles also participate in the reasoning process.

Group Thinking. Thinking and problem-solving can be done by groups as well as by individuals. In everyday life, bodies such as committees, legislatures, and juries arrive at decisions by

pooling the information possessed by individual members, by considering hypotheses proposed by several persons, and by making a final judgment by vote. Several experiments show that group thinking is usually more efficient than individual thinking. Gurnee (1936) devised a difficult maze which had thirty choice points; at each of these, three alternative paths were presented, one of which was correct and the other two incorrect. This maze was learned by 42 individuals working alone, and by 12 groups of students, averaging ten persons to a group, who decided each move by a plurality vote. On the first trial both the individuals and the groups averaged 22 errors. But on the second and subsequent trials, the groups made fewer errors by far than the individuals. Only 3 of the 42 individual subjects equaled or exceeded the groups' average on the second trial. On the sixth trial, only 2 of the individuals made no mistakes, whereas 10 of the 12 groups followed the maze without error.

An example of group thinking with more abstract and intellectual material may be drawn from the experiment of R. L. Thorndike (1938). A wide variety of problems was used, including the selection of the better of two pictures, the better of two poems, and the more significant of two newspaper headlines, and the answering of factual questions in geography, economics, politics, and current events. The "right answers" concerning the pictures, poems, and headlines had been decided by a consensus of competent opinion in preceding research studies. The problems were submitted to almost 1,200 college students who worked in 222 different groups, each consisting of from 4 to 6 individuals. First, each individual recorded his own judgment. Next a vote was taken based on these individual judgments. Third, each group discussed the problem fully and voted again on its solution. The average percentage of problems right was 61.9 for the individuals, 64.4 for the prediscussion votes of groups, and 66.2 for the group votes after discussion. These results show that group discussion increases the

correctness of judgments over and above the gain made by the collective pooling of individual opinions.

Critics of the experiments on group thinking have pointed out that the mere combination of persons into groups does not by itself always result in more correct decisions. When a majority of individuals holds to the same wrong answer, grouping will only intensify the error. If a plurality, acting as individuals, gives the right answer, or if personal errors are equally distributed among several wrong alternatives, then group judgments will be more correct than individual ones. It is only when discussion takes place in the group that the best advantages of joint thinking are realized. In a situation of free discussion, more facts are brought out, more alternative solutions are proposed, and more criticisms of suggested hypotheses are made. These factors determine the effectiveness of group thinking.

Creative Thinking

The Process of Imagination. Some instances of thinking are distinguished by the strikingly new or original character of the product evolved. The best examples of such processes come from the work of great thinkers. When an Einstein creates a new theory in mathematical physics or an Edison invents the incandescent electric lamp, they seem to go somewhat beyond the bounds of ordinary reasoning. Even more substantial illustrations of this process are found in the fine arts. The creation of a great painting or the composition of a deathless work of music is a task of which only genius is capable. Yet even this genius must think in order to create, and some analysis of the nature of his thinking can be made.

Creative thinking is the process of *imagination.* Imagination therefore represents the highest type of psychological activity, more complex in its constitution and more significant in its results than are acts of sensing, perceiving, remembering, or reasoning. In common speech, this high importance is sometimes granted to imagination and sometimes denied to it. We pay a man a compliment when we say that he is a man of imagina-

tion, but we also doubt his soundness and even his veracity when we say that he is only using his imagination. We condemn a rumor as being merely a figment of the imagination, and then praise a scientific accomplishment as being a product of great imaginative power. This confusion in the use of the term "imagination" is due to two separate influences. First, "imagination" is used in popular speech to designate daydreaming, revery, mind-wandering, or a flow of images. Idle fantasy is not imagination in the psychological sense, but is only recall and association. The second source of confusion is the fact that genuine imagination creates something new. The common man's distrust of imagination is in part a symptom of his general dislike for anything that is unfamiliar or that he does not understand. Also, the creative thinker makes some inevitable errors in his progressive drive toward a goal; but to call only these errors "figments of imagination" is unfair to the process that attains the final and creative end result.

Although great thinkers furnish the clearest and most useful lessons on the nature of imagination, it must be emphasized that many persons of lesser capability also use exactly the same processes. The modest inventor who devises a new improvement for lawn-mowers, and the domestic poet whose works (perhaps for the best) are never published, use imagination. The differences between great thinkers and little thinkers are of degree, not of kind. The process of imagination is therefore a description of a method that almost all persons use to some extent.

Imagination could be described by reference to the outline already used to analyze problem-solving and reasoning. There are some features of the imagining process, however, that are shown more clearly by a somewhat different synopsis, first proposed by Wallas (1926). This analysis distinguishes four stages in an act of imagination, of which the second and third are unique to this process. These four stages are: (1) the period of *preparation*, during which facts are learned, skills are acquired, and observations are made on which the later

imagined product can be based; (2) the period of *incubation*, in which no apparent progress toward the goal is made, and in which the thinker may seem frustrated or idle; (3) the stage of *inspiration*, in which the new creative product emerges, often suddenly; and (4) the period of *verification*, during which the inspiration is evaluated, enlarged upon, and objectified. These stages presuppose one other step that must exist before creative thought can begin at all. This is a *goal*, an aim, or a purpose toward which the thinker is working. The four principal steps of imagination will be described in more detail.

The Period of Preparation. It must not be assumed that creative imagination is all a matter of genius or inspiration. On the contrary, one gets the impression from biographical evidence that creative thinkers are uncommonly hard workers and that they have extensive information and great skill in their respective specialties. Every great creative thought is preceded by a period of preparation that usually is long and laborious, and sometimes constitutes a lifetime of effort. The period of preparation is analogous to two of the stages of reasoning, that of gaining facts and observations, and that of suggesting possible hypotheses. During preparation the thinker finds out all that he can about his problem, and gropes for an answer, trying the older conventional methods that he has learned, and experimenting with variations on these approaches. One essential step in preparation, especially in scientific creativeness, is the evaluation of the traditional solutions of the problem. Many new creative discoveries have their seed in an analysis of the shortcomings of the past.

Preparation for an act of creative thought may be deliberate or nondeliberate. In scientific discovery, deliberate preparation is most frequent. The research worker studies the tools essential to his problem, and reads the previous contributions to his field of study. Before becoming a discoverer he must first become a scholar. Nondeliberate preparation may often play an important part, however. A man who has abandoned the field of physics to take up the study of psychology

may later find that his knowledge of physics is the key to an important contribution to his newer area of interest. In fact, a characteristic of a creative thinker is his ability to combine and apply experiences that originally were gained at various times and for diverse purposes. In painting and music, deliberate preparation is important, for a mastery of techniques is a prerequisite to the invention of new effects and combinations.

Undeliberated preparation for creative work is seen most clearly in literature, especially in poetry. Many writers have kept notebooks in which they jotted down observations, chance thoughts, and bits of fact or style culled from their reading. In Coleridge's notebook, for example, may be found the germs of *The Ancient Mariner* and *Kubla Khan*. Coleridge, an omnivorous reader, assimilated the traditions and folk stories of the Far East, the superstitions of the Middle Ages, the habits of the albatross, lore about sailors and boats, and the plots of ancient Greek legends. From this heterogeneous mass of material sprang his great imaginative poems. He was not gathering material for a planned poem when he read. Instead, the material was acquired randomly and for its own sake. Only after the preparation was complete did Coleridge conceive the poems, with that ability to recombine that is a mark of genius.

The Period of Incubation. One of the most remarkable observations about creative thinking is that a period of seeming inactivity typically precedes a discovery or accomplishment. This period has been termed *incubation* because the thinker seems to be "hatching something," the value of which will be revealed later. The behavior characteristic of the incubation period varies somewhat among persons and according to circumstances. One variety of incubation appears as restless and poorly coordinated activity, accompanied by a feeling of unease sometimes approaching misery. A writer may pace the floor, scribble a few lines and throw them away, become irritable with his family, smoke too many cigarettes, and succumb too readily to passing distractions. His feeling tone is depressed,

and he is wrought up emotionally. Such a period of incubation often ends in an inspiration or sudden solution of the difficulty.

Incubation does not always occur in so obvious a form. It is sometimes reported that a scientist awakes from sleep with an inspiring solution of a perplexity, leading to the presumption that the incubation occurred during sleep. In other instances, the individual may turn to another task in the midst of which the answer to his previous problem will suddenly dawn on him. A vacation or period of relaxation will have the same effect, so that upon a return to work certain baffling difficulties are found to be clarified without deliberate effort.

Several interpretations of the phenomenon of incubation have been proposed. One explanation holds that "unconscious" mental work goes on during this period. It is quite true that work gets done and that the thinker is unaware of just how it is accomplished. The notion that an "unconscious mind" does logical and constructive thinking while the individual is occupied with something else is not acceptable to most psychologists, however. Two other explanations that are much more sound psychologically account for the facts quite as well. One useful approach holds that incubation is analogous to a plateau of a learning curve.[3] The facts and observations have all been made during the period of preparation, and have been learned so thoroughly that slight gestures and other imperceptible muscle movements can symbolize them. The thinker need not work systematically during incubation because he is so thoroughly saturated with his problem that he can reject one hypothesis by a nod of the head and represent another by a shrug of the shoulders. During incubation he is rearranging his ideas by the use of these subtle symbols, just as during a plateau in motor learning a habit is being reorganized on a higher level.

Another aspect of incubation is emphasized by the part played by sleep, idleness, and change of occupation. After continuous work on a problem many inhibitions and interfer-

[3] See pp. 131-132.

ences are set up. Relaxation allows these to die out, and permits a fresh approach to be made. When an inspiration comes in the midst of conversation or during other unrelated work, it is probable that some unnoticed stimulus has provoked a return to the original problem, which is solved immediately because of the absence of the old conflicts and confusions.

The period of incubation gives rise to anecdotes about the absentmindedness of creative thinkers. A chemist reported that on one morning he took a bath, shaved, and then took another bath. Only after the second bath did he realize that he had been concentrating on a problem for some time and that his reactions to his customary morning duties had been automatic and inattentive. The "absent-minded" scientist or author is very present-minded toward his real interests, and is inattentive only to things that are inconsequential to his problem.

The Stage of Inspiration. The creative process is often fulfilled abruptly, under circumstances that justify the use of *inspiration* as a descriptive term. Wallas called this third stage "illumination," which is also apt. Inspiration is characterized by three salient qualities. It is typically sudden, it is accompanied by a peculiar emotional feeling of elation, and it often seems to come from some mysterious force external to the thinker. The suddenness of inspiration is its most interesting psychological feature, in contrast to the slow progress of motor trial and error. This swift termination of the incubation period may be regarded as a perceptual rearrangement of the material of the problem. Many combinations of facts and observations have been tried, both deliberately during the preparatory period, and implicitly during incubation. Sooner or later, if the thinker has sufficient ability, a suitable hypothesis or significant combination of ideas will occur. When it does come, it will be recognized at once as the desired solution. Inspiration, therefore, is not an isolated stroke of genius, but a culmination of all the preceding labor. It is very similar to "in-

sight" in learning, evidences of which have been found in the behavior of animals lower than man.

The remaining characteristics of inspiration, namely, the feelings of elation and of unreality, also merit explanation. Elation typically accompanies the completion of a task and the release of tension that follows the successful termination of any activity. It occurs in many less exalted situations than creative thinking as, for example, in the jubilation of a student body after a football victory. Since the importance of a creative thought is apparent to the thinker, his elation is correspondingly great.

Especially in the literary sphere, creative artists have been prone to ascribe their inspirations to sources outside of themselves. The ancient Greeks were inspired by the Muses, so they thought, and as great a poet as Goethe wrote to his friend Schiller, "We can do nothing but pile up the wood and let it dry; it will catch fire in due time, and we wonder over the occurrence." The impersonal reference of inspiration probably arises from two sources. First, the great thinker is genuinely modest and does not recognize that so good an idea could have come from his unaided efforts. Second, he does not understand the psychological processes of preparation and incubation that have preceded his creative revelation. From the evidence, it seems that artists and poets are more prone to ascribe their inspirations to outside powers than are scientific workers.

The Period of Verification. In the final period of verification, the creative process again settles down to hard labor. The scientist who has conceived a brilliant hypothesis must test it by further experiments, comparisons, or calculations. In some instances his "inspiration" may prove to be faulty, either as a whole or in part, and additional preparation and new insight may be required before he can proceed further. The labor of verification is present in the fine arts as well as in the sciences. The painter must transfer his inspiration to the canvas, and the musician must work out his broad con-

ception in terms of melodies and harmonies. In literature there is ample evidence of deliberate revision and elaboration before a poem or an essay is finally acceptable to its writer. Manuscripts of great authors show much crossing out and interpolation. The final stage of writing is not an easy task, even for those who are most able.

The sciences and the arts judge their creative products by different standards which, in fact, define the distinction between these two areas of creative activity. The scientist's standards for verification are deliberately impersonal. He evaluates his new theory in terms of its agreement with known facts and its ability to predict further conclusions which can be substantiated by direct observation and experiment. The scientist therefore verifies his inspiration by observations that other persons can repeat and confirm.

The artist, whether painter, musician, or author, has a personal standard of verification. His final task is to *objectify* his inspiration rather than to prove it, to express it in the forms of colors and shapes, keys and notes, or words. If the artist succeeds in making a worthy representation of his inspiration he is satisfied. This is what the poet meant when he wrote:

> 'Beauty is truth, truth beauty,'—that is all
> Ye know on earth, and all ye need to know.[4]

The truth of the artist is the objectification of his personal experience; the truth of the scientist is the verification of his impersonal observations.

Creative Thinking in Science. Several creative thinkers with a bent for introspection have left reports of how their novel ideas came to them. These accounts are probably oversimplified, but they serve the purpose of illustrating the creative process as seen by the person who is carrying it out. Henri Poincaré, the celebrated French mathematician, has given one such description.

[4] John Keats, "On a Grecian Urn."

It is time to penetrate deeper and to see what goes on in the very soul of the mathematician. For this, I believe, I can do best by recalling memories of my own. But I shall limit myself to telling how I wrote my first memoir on Fuchsian functions. I beg the reader's pardon; I am about to use some technical expressions, but they need not frighten him, for he is not obliged to understand them. I shall say, for example, that I have found the demonstration of such a theorem under such circumstances. This theorem will have a barbarous name, unfamiliar to many, but that is unimportant; what is of interest for the psychologist is not the theorem but the circumstances.

For fifteen days I strove to prove that there could not be any functions like those I have since called Fuchsian functions. I was then very ignorant; every day I seated myself at my work table, stayed an hour or two, tried a great number of combinations and reached no results. One evening, contrary to my custom, I drank black coffee and could not sleep. Ideas arose in crowds; I felt them collide until pairs interlocked, so to speak, making a stable combination. By the next morning I had established the existence of a class of Fuchsian functions, those which come from the hypergeometric series; I had only to write out the results which took but a few hours.

Then I wanted to represent these functions by the quotient of two series; this idea was perfectly conscious and deliberate, the analogy with elliptic functions guided me. I asked myself what properties these series must have if they existed, and I succeeded without difficulty in forming the series I have called theta-Fuchsian.

Just at this time I left Caen, where I was then living, to go on a geologic excursion under the auspices of the school of mines. The changes of travel made me forget my mathematical work. Having reached Coutances, we entered an omnibus to go some place or other. At the moment when I put my foot on the step the idea came to me, without anything in my formed thoughts seeming to have paved the way for it, that the transformations I had used to define the Fuchsian functions were identical with those of non-Euclidean geometry. I did not verify the idea; I should not have had time, as upon taking my seat in the omnibus I went on with a conversation already commenced, but I felt a perfect certainty. On my return to Caen, for conscience's sake, I verified the result at my leisure.

Then I turned my attention to the study of some arithmetical question, apparently without much success and without a suspicion of any connection with my preceding researches. Disgusted with my failure, I went to spend a few days at the seaside, and thought of something else. One morning, walking on the bluff, the idea came to me, with just the same

characteristics of brevity, suddenness and immediate certainty, that the arithmetic transformations of indeterminate ternary quadratic forms were identical with those of non-Euclidean geometry.

I returned to Caen, I meditated on this result and I deduced the consequences. The example of quadratic forms showed me that they were Fuchsian groups other than those corresponding to the hypergeometric series; I saw that I could apply to them the theory of theta-Fuchsian series and that consequently there existed Fuchsian functions other than those from the hypergeometric series, the ones I then knew. Naturally, I set myself to form all these functions. I made a systematic attack upon them and carried all the outworks, one after another. There was one, however, that still held out, whose fall would involve that of the whole place. But all my efforts only served at first the better to show me the difficulty, which indeed was something. All this work was perfectly conscious.

Thereupon I left for Mont-Valerian, where I was to go through my military service; so I was very differently occupied. One day, going along the street, the solution of the difficulty which had stopped me suddenly appeared to me. I did not try to go deep into it immediately, and only after my service did I again take up the question. I had all the elements and had only to arrange them and put them together. So I wrote out my final memoir at a single stroke and without difficulty.[5]

The stages of preparation, incubation, inspiration, and verification can be traced clearly in Poincaré's description, which confirms the analysis of creative thought into these steps.

Creative Thinking in Art. Some accounts of the creative process have been given by painters and musicians, especially by writers. For variety of evidence, however, a study that approaches this question experimentally may be cited. Patrick (1937) observed the work of 50 artists in a partially controlled situation, and made a valuable statistical analysis of her data. In the experiment a selection of poetry rich with vivid imagery, taken from Milton's *L'Allegro*, was read to the artist. He was then asked to draw a picture about the poem, or about anything that it suggested to him. The experimenter recorded everything that the artist said, and made a detailed description of the progress of his work. This record

[5] H. Poincaré, *Foundations of Science,* Lancaster: The Science Press, 1913, pp. 387-388.

was afterward analyzed statistically, in terms of the percentage of certain activities that fell in each quarter of working time. The results, in condensed form, are given below:

	Quarter of Working Time			
	1	2	3	4
Preparation (thought changes) . . .	80	15	3	2
Inspiration (shapes drawn)	20	42	29	9
Verification (revisions)	3	17	34	46

The results showed evidence of *preparation* in the number of thought changes or modifications of the trend of drawing and comment. Four-fifths of all thought changes occurred during the first quarter of the artists' working time, indicating deliberate trial and error attempts during this period. *Incubation* was found in four-fifths of all cases. This factor was judged to be present when an idea from the poem appeared early, was abandoned, and then reappeared suddenly after an interval of time devoted to other approaches or comments. The presence of *inspiration* was noted when the artist drew rapidly the general shapes of his picture. This occurred chiefly in the second and third quarters of the time, and more in the second quarter than the third. *Verification* was shown by the number of revisions or retouchings and by adding shading or unessential detail. These acts were found most often in the last half of the working period, and reached a peak in the fourth quarter.

Four-fifths of the artists, in response to planned questions that were asked after the drawing was complete, stated that the experiment was representative of the way in which they usually worked. The artists also contributed a number of comments about their typical experiences which show very clearly the presence of incubation and inspiration. Some of their remarks follow:

"I almost always carry an idea around a while in my mind before I start to work. It keeps coming back several times while I am doing other things, and I can work it out later. Sometimes I lose it if I don't work

on it. In coming back it changes, and sometimes improves as it comes back. If I don't grab it I may get something different."

"I incubate an idea for periods of two or three weeks. It may be for a month or more when I am not working on it. I think now of making a picture of Coconut Grove as it used to look, and I have been incubating that two years. Then I get to feel like I want to paint. I keep vaguely thinking of something like it to do. I am thinking now of a still life. This afternoon I may start on it. The idea recurs while I am doing other things, as I have thought of a still life for two or three weeks now. I think of the roundness of the fruit, and shapes against the glass bottle. It recurs in color, so when I am ready to paint I know what I want to do and do it very rapidly. A complicated thing becomes simple by thinking about it. I noticed a tree and did not think about it and before I knew it, I had all sorts of information for making it."

"I often carry an idea around for several weeks before I make a picture though sometimes longer. I got ideas in Santa Fe last summer to do now. The ideas recur from time to time while I am occupied with other things."[6]

That ordinary persons employ the same sequence when they attempt to do creative work was shown by another part of this experiment. A "control group" of 50 nonartists attempted to draw pictures under the same conditions. They too showed the four stages of thinking, although their drawings were inferior not only in skill, but also in scope and interpretative power. The nonartists complained more often of their inability to objectify their ideas in the drawing.

Improving One's Thinking

A study of the psychological processes of reasoning and imagining should provide some suggestions by which people may improve the efficiency of their own thinking. Experiments indicate that mere practice in one kind of reasoning does not transfer automatically to other tasks of different sorts. A student who studies logic may become adept at manipulating syllogisms, and one who masters geometry may gain skill for solving other geometric problems. But these accomplishments will not necessarily make them any more adept at reasoning

[6] C. Patrick, "Creative Thought in Artists," *Journal of Psychology,* 4:35-73, 1937.

in biological, social, or economic spheres. On the other hand, a broad insight into the methods of reasoning can cause substantial gains in any field in which the individual takes the pains to apply them.

The first requirement for sound reasoning is a clear conception of the problem to be solved or the goal to be achieved. Many students fail to master a technique that requires reasoning because their goal is the shallow one of getting the right answer, reproducing what the book says, or securing a good mark in the subject. Only by an understanding of the real significance of the result to be accomplished can efficient reasoning be started. Civic thinking suffers from the same disability. The voter cannot reason in his decision among candidates for office unless he has some awareness of the ends to be served by government. To reason well, therefore, one must know the outcome that is sought.

A second feature of right thinking is the need for facts, evidences, and previously suggested explanations. The material of thought from which the new emerges is the perception and recall of the old. In order to think about a problem, it is necessary to know about it. This obvious statement points to a common error of educational doctrine. Teachers often assert that they do not want to teach their students facts, but that they wish to teach them to think for themselves. This is impossible, for an absence of information has never produced a worth-while new idea. Admittedly, to cram students with undigested facts alone is undesirable. The slogan, however, should never be "not facts but thought"; instead it should be "facts *and* thought." It also saves time to know the history of one's field of endeavor, so that no effort is wasted in the pursuit of an hypothesis long since disproved. Great thinkers have been scholars, and great artists have been skillful; there is no evidence that originality is ever contaminated by knowledge.

When the goal is set and the data are collected, the next task of reasoning is to suggest various hypotheses that may explain the facts or solve the problem. The inadequate thinker

often stumbles here. He proposes one or two possible answers, rejects them for good reasons, and then is baffled because he can invent no further alternatives. When this happens, some procedures based on the "incubation" stage of creative thinking are helpful. A change of activity, some recreation or relaxation may serve to release the inhibitions against new ideas. Upon a return to the task the persistent errors may have vanished, and a fresh approach can be made. During the hypothesis-forming stage of reasoning, it is justifiable to make suggestions uncritically and perhaps even wildly. The larger the number of possible solutions proposed, the more likely it is that one of them may be verifiable, or at least that one will suggest a further and profitable line of investigation.

Many inadequacies of reasoning arise from a failure to apply rigorous tests to a proposed hypothesis. An attractive but incorrect explanation may be accepted uncritically, without further deductions or experiments to substantiate its validity. If the first solution that occurs is adopted without verification, no other proposals will be entertained, and the individual may therefore never discover a better answer. Two aids to the verification of reasoning are *experiment* and *logic*. Experiment puts the conclusion to the test of practice under controlled conditions. Logic tests a conclusion by reference to formal rules that have been evolved by generations of thinkers. Logic is not a description of thought, for people do not solve their real difficulties in any such stilted manner. It is a yardstick for evaluating an end result of thinking that has already been discovered by the creative process. The value of logic may be shown by an illustration. In one experiment, a large majority of a group of college students stated that the following syllogism was sound:

> All Mongolians have slanting eyes,
> Chinese have slanting eyes,
> Therefore, Chinese are Mongolians.

The scholar trained in logic immediately recognizes that this syllogism is faulty because it contains the classic error of the "undistributed middle term." This error may be made clear to anyone by stating:

> All Mongolians have two legs,
> Englishmen have two legs,
> Therefore, Englishmen are Mongolians.

In cases such as this, logic is of value in detecting plausible but spurious conclusions of thought.

An individual who has a keen perception of the task or problem to be solved, who has an adequate command of the facts and observations that pertain to it, and who can suggest solutions freely and criticize them rigorously, will do effective thinking. This is the method of the great thinkers, but it is applicable to lesser intellects and to humbler problems.

Chapter XIV

ABILITIES AND THEIR MEASUREMENT

Psychological Measurement

Individual Differences. Psychology is most concerned with the traits that human beings possess in common. Everyone learns, acts, senses, perceives, remembers, and thinks. It is important to notice, however, that all people do not perform these functions equally well, or in exactly the same manner. In addition to the common characteristics that mark him as a human being, each person has *individuality* that distinguishes him from his fellows.

Individual differences exist in all biological traits, and some of them are clearly noticeable in everyday life. People differ in height, in weight, in the volume of air they can inhale, and in strength of grip. When such a characteristic is measured carefully, a continuous variation is found. Height, for example, varies in imperceptible degrees from that of the tallest man to that of the shortest. Measurement also reveals with precision another ordinarily noted fact, that most persons are of nearly average height, and that the number of individuals decreases as extremes of shortness or tallness are approached. This is termed the *normal distribution* of a trait, and is approximated by most biological measurements (Fig. 105).

Psychological characteristics also can be measured, and are found to conform to the same principles of distribution. Fig. 106 shows the distribution of the speed of tapping of a group of 128 adults, the unit of measurement being the number of taps made with a stylus on a metal plate in an interval of fifteen seconds. Fig. 107 illustrates the variation of a more com-

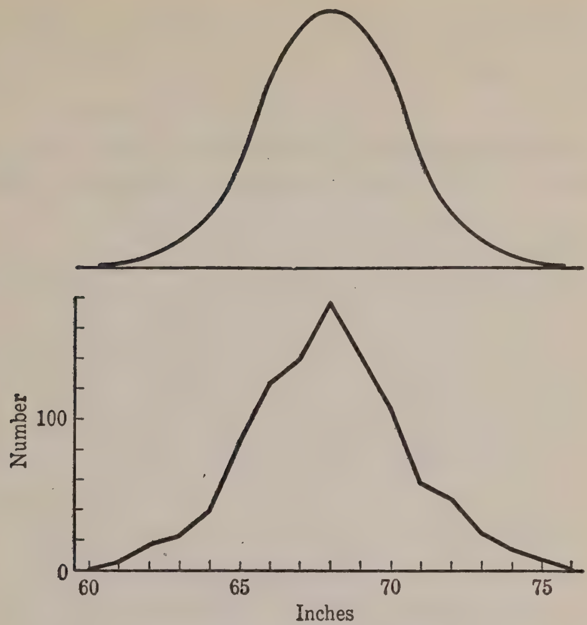


FIG. 105. Distribution Curves.

At the top is the mathematical "normal curve" of distribution. Below is a distribution of the heights of 1,000 Cambridge University students (after Yule), which closely approximates the normal distribution. In each case, the height of the curve above the base line shows the number of persons having the indicated degree of the trait.

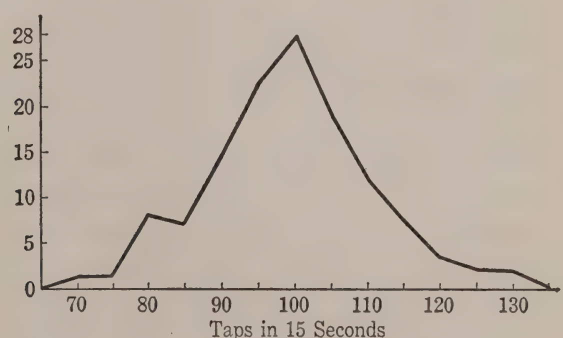


FIG. 106. Individual Differences in Speed of Tapping.

A group of 128 adults shows variation from 70 to 130 in the number of taps made in 15 seconds.

plex function which might be described as a simple test of imagination. Forty college students were instructed to make all possible words from the letters AEIRLP. The number of words constructed in three minutes varied from ten to twenty-eight. Although the graph of this distribution is more irregular because of the small number of subjects, it shows the

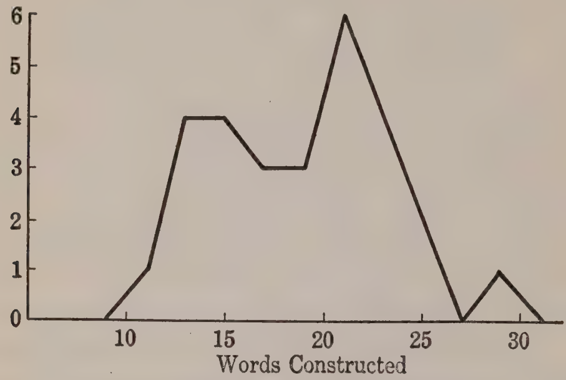


FIG. 107. Individual Differences in the Word-building Test.

The task was to construct all the words possible from the letters AEIRLP in 3 minutes. Forty college students constructed from 10 to 28 words.

general tendencies common to all measurable functions. In general, persons display the same *kinds* of traits but differ quantitatively in the *amount or degree* of a trait.

Abilities and Typical Reactions. Psychological measurement has been applied to two principal aspects of human behavior. Many measures are concerned with *how well a person can do a task.* For this purpose a characteristic is measured under conditions in which the subject has the motivation and opportunity to do his best. This procedure elicits and measures an *ability.* Ability means the power to perform a task. Psychological abilities that can be measured vary greatly in complexity. Strength of grip, speed of movement, and reaction time are examples of rather simple abilities. Somewhat more complex are various tests of learning, perceiving, and recalling. Other still more complicated abilities cannot be

classified under particular psychological functions. Solving problems in arithmetic, writing essays, and designing machines are abilities in which all the principal mental traits operate in inseparable interrelationships.

Other psychological measurements of equal importance try to discover the *typical reactions* of an individual rather than his abilities. A person's ability and his typical use of that ability are rarely identical. For example, we may observe an individual's use of English grammar when he is striving to do his best and when he knows that he is being tested, thus measuring his ability. Or we may observe his usual habits of English when he is unaware of being watched, as a measure of his typical behavior; this in most instances would be inferior to his best ability. Some forms of behavior can be measured significantly *only* in terms of typical reactions. A test of the ability to be honest, for example, will elicit nothing but perfect honesty if the subject knows that he is being tested. Honesty must be measured when he is unaware that a test is being made, so that he carries out the reactions typical of his ordinary behavior. Similarly, psychology is interested in typical behavior rather than in ability when measuring social traits such as fair-mindedness, self-confidence, dominance, or sociability.

The problems involved in the measurement of abilities are therefore somewhat different from those encountered in the measurement of traits of personality or character. This chapter describes some methods for measuring ability, and some conclusions that are drawn from these measurements. Typical reactions, which constitute the personality and character traits of the individual, are dealt with in the next chapter.

Methods of Measurement. Both in everyday experience and in the more exact work done by psychologists, measurements are interpreted by comparing one individual with others. We ordinarily judge a person to be tall or short because he differs in height from the average of the people whom we are accustomed to see. A person five feet tall would be a giant

among the African pygmies, but he would be regarded as undersized among European peoples. That a certain child can solve eighteen of a given set of arithmetic problems yields no information about his ability in arithmetic unless we know what other children of the same age and training can do. Knowing how many problems the average child can solve furnishes the only valid basis for judging whether some one child is superior, average, or inferior. This holds for all psychological measurements, whether of abilities or of typical reactions.

In order to compare individuals fairly and precisely it is necessary to give them the same task under identical conditions. Many errors that common opinion holds concerning psychological traits arise from ignorance of this rule. For instance, we may judge that one person is given to violent temper and that another person is calm, whereas the real difference lies in the fact that we have observed the first person only in exasperating circumstances, while the second person has not been so observed. A *psychological test* is an attempt to minimize such errors. A number of individuals are given exactly the same task under exactly the same conditions. When the results are scored in a uniform manner, they yield comparable measures of ability in the trait that is tested.

The primary units of measurement employed in psychological tests are *time*, *number*, *difficulty*, and *quality*. In some tests, the length of *time* required to perform a certain number of tasks is recorded, or else the number of tasks that can be completed in a stated period of time, which amounts to the same thing. If the time is short and the subject is highly motivated to work rapidly, the test is primarily a measure of *speed*. Speed is not of supreme importance in the more complex mental processes, but some time limit, even though it is a generous one, is usually employed to make the test conditions uniform. The *number* of things a person can do is significant in testing his breadth of information or of skill. Probably the most important psychological measure is *dif-*

ficulty. Some persons can accomplish tasks that others cannot do at all. The difficulty of a task is defined objectively in terms of the proportion of people that can do it. A problem that only ten per cent of adults can solve is, by definition, more difficult than one that can be solved by eighty per cent of adults. *Quality* usually enters into measurement, since a certain standard of achievement is required if the response is to be scored "correct" or "successful." In some tests, quality is measured by comparing the product created by a person with those made by other individuals.

A psychological test involves the following essentials of measurement: (1) a uniform task, (2) performed under identical conditions, (3) yielding scores of time, number, difficulty, or quality, (4) which are compared to the scores of other individuals.

Mental Tests

General Mental Ability. In recent years psychologists have devoted considerable effort to the construction of tests of general mental ability or *intelligence*. For many centuries common observation has recognized that persons differ in the general efficiency with which they function mentally. It was noted that some individuals were brighter than the average, while others were duller. These individual differences are manifested by variations in the speed and depth with which new ideas are grasped, by differences in the ability to learn in school or later, by the ease or difficulty with which adjustments to new circumstances are made, and in many other ways. General mental ability cannot be ascribed to the excellence of any one function such as learning, perceiving, remembering, or thinking. It depends upon the general excellence of all these processes, and upon the way that they operate together.

In theory, general mental ability or "intelligence" is usually defined as the *capacity* for performing intellectual tasks successfully. This definition distinguishes between *capacity* and *ability*. Ability is the power to perform tasks, and usually

arises from training. If two boys differ in arithmetical ability, for example, the most usual reason is that one has had more or better training than the other. But two persons may receive equal training in a function, without attaining equal ability. This is due to the greater aptitude, facility, or capacity that one shows for acquiring the function in question. Capacity is thus revealed by the differences in ability that appear under conditions of equal training. Capacity cannot be measured directly; but when opportunity, motivation, and training are equal, capacities are proportional to the abilities to which they give rise. "Intelligence tests" endeavor to measure capacities in this *indirect* manner.

The general mental tests that are available at present achieve the aim of measuring capacity only imperfectly. Psychologists recognize this, and are inclined to be moderate in their interpretations of intelligence test scores. No mental test scores can be assumed to be absolutely and invariably accurate, but they are sufficiently exact to serve a number of useful purposes. Moreover, technically trained experts in psychology know just how accurate or inaccurate each test is, in terms of the *probable error* of its score. This is taken into account in making interpretations. Laymen, because they lack the necessary technical information, are usually extreme in their judgments of the value of mental tests, being either unduly enthusiastic or excessively critical. One layman who "believes in" intelligence tests may regard them as infallible instruments which tell all that is significant about a person, whereas another may reject them as entirely worthless and misleading. Both extreme views are wrong, and both arise from lack of sufficiently detailed information.

Certain fundamental principles are used in the construction of all intelligence tests, as contrasted with tests of specific achievement. First, intelligence tests try to measure *complex mental functions*. This is necessary because intelligence is not just the sum of an individual's perceiving, remembering, and thinking, but is a product of all these functions working to-

gether. A second requirement concerns the material used for testing purposes. This material must be *equally familiar to all* the individuals of the group or category to be tested. This aim is hard to achieve in practice, but a persistent attempt is made to fulfill it. Tasks are chosen from the common environment with which all subjects may properly be assumed to have had contact. Or tasks may be chosen that are entirely novel, presenting unusual problems that no one will have met in everyday life. Schoolish items, or tasks that are appreciably affected by specific educational advantages, are avoided in the construction of intelligence tests.

A third requirement is that the tasks employed in all tests of general mental ability must be *selected experimentally*. No psychologist, no matter how expert, decides by armchair speculation what intelligence is. Tests are constructed to fit human beings; human beings are not fitted to arbitrarily devised tests. The chief experimental basis for selecting test items is that they must *correspond to other criteria of intelligence*. They must be tasks that older children perform better than younger children, that persons judged as being bright by a consensus of competent opinion do better than those judged to be average or dull. An intelligence test must predict the future intellectual success of individuals, and the items selected are those that have been shown experimentally to possess this predictive value. Elaborate mathematical procedures are used in test construction to obtain valid items and to verify the merit of the whole examination.

Individual Mental Tests. The standard method of measuring general mental ability is the *individual intelligence test*, which is constructed according to principles developed by Alfred Binet between 1898 and 1911. His first scale, the pioneer intelligence test of the modern type, was published in 1905. In administering an examination of this sort, the examiner sits alone with the person being tested and asks a standard set of questions. Most of the questions and responses are oral, but some use is made of pictures, diagrams, and minia-

ture objects, especially with young children. The task is presented to each subject in exactly the same way, and the responses are scored according to uniform rules. In his original experiments with tests, Binet was the first to use complex mental tasks selected from the common environment, according to the principles that have just been discussed. His tests therefore attempt to measure the ingenuity and resourcefulness of the child, rather than how much information he has acquired.

Binet also introduced several techniques for experimentally determining standards of attainment. First, his experiments showed that a task could be performed by an increasing proportion of children with increase in age. Some actual data of this type follow:[1]

Name of Task	Per Cent of Children of Each Age Who Passed							
	4	5	6	7	8	9	10	11
Counting 13 pennies	30	46	76	93	96	..	..	..
Defining 20 words	..	..	..	12	56	78	97	..
Repeating 4 digits backward	..	..	..	18	44	62	75	86

It may be seen from the table that "counting 13 pennies" is a six-year task, since it can be done by more than half of the six-year-old children, but by less than half of those who are younger. Similarly "defining 20 words" (of a given list) is an eight-year task, and "repeating 4 digits backward" is a nine-year accomplishment. Note that the age level of a task is determined by the fact that children of that age *can* do it, and not because any psychologist thinks that they *should* be able to do so. These data are the basis of the concept of *mental age*. In the Binet scale, each test or task is assigned to an experimentally determined age level. A child who can perform the ten-year tests but not the eleven-year tests has a mental age of ten years, regardless of his chronological age. This

[1] From the 1916 Stanford Revision of the Binet Tests. L. M. Terman, *et al., The Stanford Revision and Extension,* Baltimore: Warwick & York, 1917, pp. 165-178.

means that his ability to do the problems is equivalent to that of the average ten-year-old child.

The Binet tests have been adapted for use in the languages of most countries of the world. In the United States the *Revised Stanford-Binet Scales*, constructed by Lewis M. Terman and Maud A. Merrill of Stanford University, are most widely used. An examination of some sample parts of this scale shows the nature of the problems included. There are a number of tests, usually six, at each year of mental age from two years to "superior adult." Only two specimens from each level are given here.

Year Six

—Copying a bead chain from memory, after watching the examiner string alternate round and square beads.
—Detecting missing parts of mutilated pictures of objects (4 of 5).

Year Eight

—Detecting the absurdity of statements such as "An engineer said that the more cars he had on his train, the faster he could go" (3 of 4).
—Answering with understanding questions such as "What makes a sailboat move?" (2 of 3).

Year Ten

—Finding an absurdity in a specially prepared picture.
—Naming 28 unconnected words in one minute.

Year Twelve

—Knowledge of words from a vocabulary list up to the level of words such as "lecture," "skill," "juggler."
—Repeating five digits reversed, that is, in the opposite order to that in which they are heard (1 of 3 trials).

Average Adult

—Deciphering a simple code, and writing a word in that code.
—Giving the abstract meaning of proverbs (2 of 3).

Superior Adult

—Making up a sentence containing three given abstract words (2 of 3).

—Repeating the thought of a difficult paragraph on "The Value of Life," read to the subject.
—Repeating nine digits (1 of 3).

These tasks conform to the criteria for a mental test. They are a series of definite tasks, administered and scored in a uniform manner. The scoring is definite but not arbitrary. In Year Ten, for example, a test is to name 28 words in one minute, because that is what ten-year-olds can do. To require some other number would change the difficulty of the task and move it to another year level.

In the practical administration of the Stanford-Binet Scale, various age levels are given to the child until the highest level is found at which he passes all subtests. Higher levels are then administered, until he can succeed in none of the tasks. The basic age level at which he can do all the tests, plus partial credits for successes above that level, determines the mental age.

Another useful score obtained from an individual mental test is the *intelligence quotient* (I.Q.). This is found by dividing the mental age (M.A.) by the chronological age (C.A.) and expressing the result as a percentage.

$$\text{I.Q.} = \frac{\text{M.A.}}{\text{C.A.}} \times 100$$

Since, by definition, the mental age of the average child equals his chronological age, the average I.Q. is 100. If a dull twelve-year-old has a mental age of 10, his I.Q. is $10/12 \times 100 = 83$. An above-average twelve-year-old who tests at mental age 14 on the scale has an I.Q. of $14/12 \times 100 = 117$. The intelligence quotient is useful in comparing the brightness of children of different ages, since 100 is normal at any age, and 120 represents the same degree of superiority whether the child is six or twelve years old. Fig. 108 shows a distribution of the intelligence quotients of 2,904 school children. Most I.Q.'s are near the center of the distribution; those below 60 or above 140 are sufficiently infrequent to be exceptional.

The interpretation of intelligence quotients is aided by descriptive verbal terms. The following interpretative sugges-

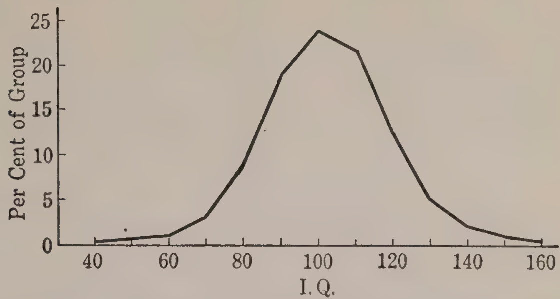


FIG. 108. Distribution of Intelligence Quotients.

The intelligence quotients of 2,904 children tested with the Revised Stanford-Binet Scales. (After Terman and Merrill, 1937.)

tions follow those of Merrill (1938) for the Revised Stanford-Binet Scale.

I.Q.	Verbal Description	Percentage in Each Group (Among 2,904 Children Tested)
140 and above	Gifted	1
130–139	Very superior	3
120–129	Superior	8
110–119	High average	18
100–109	Average	23
90– 99	Average	23
80– 89	Low average	15
70– 79	Inferior	6
60– 69	Borderline	2
Below 60	Mentally defective	1

Performance Tests of Mental Ability. An obvious shortcoming of the Binet test is its use of language, which means that children from homes in which English is not spoken, and persons with other special language handicaps, cannot be tested fairly. For such individuals the necessary condition of "equal familiarity to all" has been violated. To overcome this defect a number of nonlanguage or *performance tests* of gen-

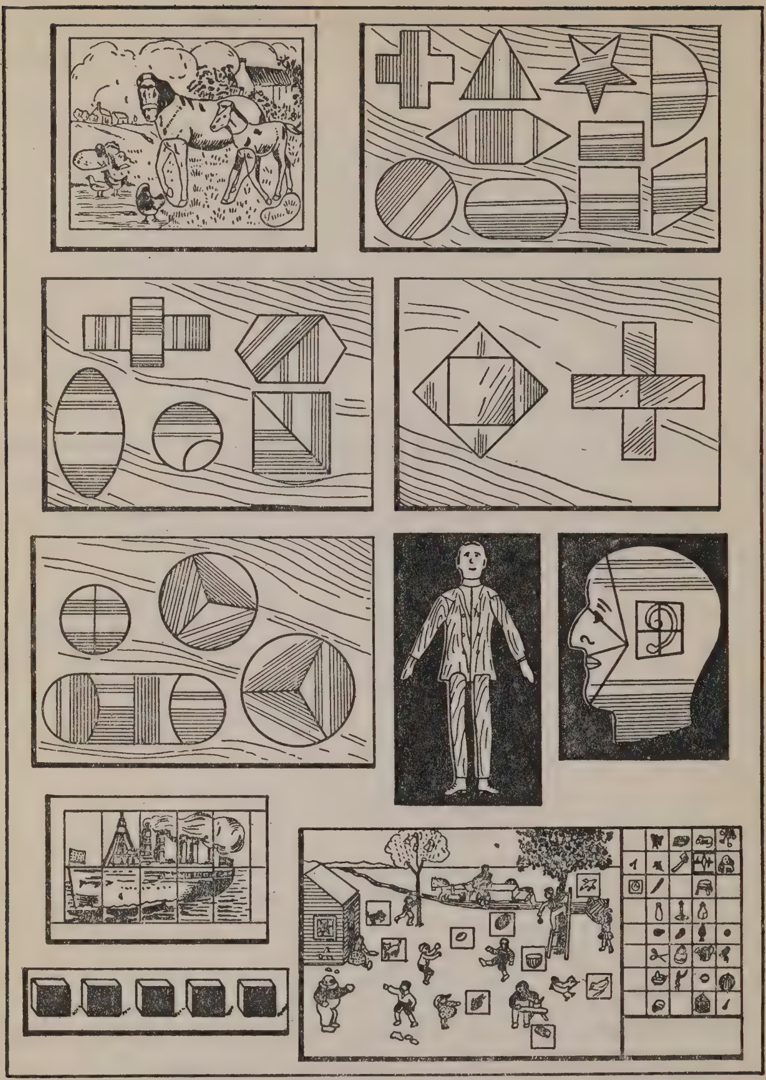


FIG. 109. Performance Tests.

Ten tests of the Pintner-Paterson Performance Scale are shown. Left to right, by rows, they are: The Mare and Foal Form Board, the Seguin Form Board, the Five Figure Form Board, the Two Figure Form Board, the Casuist Form Board, the Manikin, the Feature Profile, the Ship Puzzle Test, the Healy Pictorial Completion Test No. I, and the Knox Cube Test. (Courtesy of C. H. Stoelting Co.)

eral mental ability have been devised (Fig. 109). These require no spoken responses, and some of them can be administered without oral instructions.

Among the principal types of performance tests are *form boards* which require the examinee to be alert to spatial relationships while fitting blocks into receptacles. Another is the *picture-completion* test, in which blocks of the same shape are inserted so as to make the best sense with the rest of a picture. This kind of test can be made very subtle and difficult. Various nonverbal tests of *learning and memory* are also used. In these the subject must tap blocks in the same order that the examiner does, or reproduce drawings that he has seen for a short time. In the *maze tests* the subject is called upon to find his way through a series of printed mazes, looking ahead to avoid errors.

Like the Binet tests, performance tests are tried out experimentally, and only those of proved value are used. Standards are ascertained by finding the average scores made by children of various ages, so that a mental age can be determined for each separate test. To increase reliability, the results of ten or more performance tests are usually averaged to secure the final mental age for the examination. Intelligence quotients can be computed from the mental and chronological ages.

Group Mental Tests. The use of individual tests is restricted because of the cost of administering them. To test one child takes the exclusive time of a trained examiner for one hour or more. To meet this difficulty, *group tests* have been devised in which the questions are printed and the answers recorded in pencil. This permits the testing of a large number of individuals at one time. Group tests contain items such as the following:

Underline the correct answers.

1. One number is wrong in this series. Which one? 2, 4, 3, 5, 4, 6, 5, 9, 6, 8.
2. The words *contingent* and *dependent* mean: same—opposite—neither same nor opposite.

3. *Abundant* is to *cheap* as *scarce* is to: plentiful—costly—hoard—restricted.
4. Write the letter of the alphabet that is the fourth to the left of the letter midway between G and K. . . . . ——.

The preparation of a group mental ability test is an experimental process, like that of constructing an individual test. First, a large number of short tasks are formulated by the test-maker. Next, these are tried out on a large number of individuals about whose abilities other information is available, such as the results of Binet tests, or a record of school advancement, or the estimates of competent observers who know these individuals. Every item of the proposed group test is checked against these criteria. The items whose results correspond well with the criteria are kept, and those whose results do not check are thrown out. In no case is an item retained because an expert thinks that it is a good test of intelligence. Items are selected because they show results that correspond to other facts. The standards on the final form of the test are now determined. The *norm* for twelve-year-olds is the average number of points made by children of that age, and anyone scoring that same number of points has a mental age of twelve.

In some mature groups, such as college students, age is not an important factor in mental ability. In these instances it is usual to interpret test scores in terms of *percentile rank* (P.R.). An individual's percentile rank is the percentage of persons in the defined group whose scores are lower than his. Thus a P.R. of 30 means that the individual excels thirty per cent of the group, a P.R. of 50 is average, and a P.R. of 95 indicates a score excelled by only five per cent of the group. In no case are standards determined by what anyone thinks they should be. They are determined experimentally by recording the performances of people who have taken the test.

Group tests are even less valid measures of pure mental capacity than are the individual tests. Scores on group tests are influenced by differences in reading ability, and even by variations in familiarity with pencil and paper. Often a low

score on a group test is due to slow reading habits, not to general inability. The same factors that cause low scores on group tests, however, are also likely to be handicaps in school. Group tests are therefore useful instruments for predicting scholastic success. They give an indication of the present effective mental ability of individuals, but they are greatly influenced by cultural environment and schooling.

The Analysis of Mental Ability. The use of an all-inclusive single intelligence test score such as mental age has considerable value. But since common observation shows that all people of the same intelligence are not exactly alike, such a measure of an individual's net total intelligence fails to give an entirely true picture of the situation. One person, for example, may have an especially good capacity for literary expression, while another of equal total ability may have a greater aptitude for mathematics. In the earliest experiments with mental tests, from about 1890 to 1910, many attempts were made to analyze mental capacities in terms of familiar psychological functions. During this period various tests were labeled as measures of "speed," "perception," "attention," "observation," "memory," "reasoning," and the like. These early tests were not successful in practice. Their results did not correspond closely to other measures of intellect, and did not prove helpful in the prediction of success in school or in later occupations. Moreover, such tests did not agree well among themselves. For example, there were large discrepancies in various tests all of which were supposed to measure "memory." Because of these defects analytical tests were almost entirely abandoned after Binet's work on the measurement of general intelligence became known.

Recently there has been a revival of interest in analytical mental tests because of the development of new mathematical methods that make the analysis more dependable. Thurstone (1938) has published Tests for Primary Mental Abilities that distinguish seven mental components or factors. These are: (1) the perceptual factor, (2) the number factor, (3)

the verbal factor, (4) the visual space factor, (5) the memory factor, (6) the inductive thinking factor, and (7) the deductive reasoning factor. The construction of these tests employs the complicated mathematical method of *factor analysis*, a procedure which sorts out tests or tasks into groups. The tasks within each group are statistically coherent and related, but they are in large degree unrelated to the measures in any other group. By this technique, the groups are first discovered by an experimental analysis. Each group discovered is then named according to its apparent content. This is the opposite of the earlier method which named the functions first by means of an arbitrary "armchair" analysis, and then attempted to measure each function. The extension of this new method may make the results of mental tests more meaningful and useful.

Mental Development

Development During Childhood. Mental tests give some indication of the nature and rate of growth of the intellectual functions during childhood. First, the contents of age-level tests give detailed facts about mental growth and show the performances that may be expected of children of various ages. Second, the numerical scores on mental tests provide some insight into the rate at which intellectual ability grows from year to year. Test results are also useful to show the age at which mental maturity is reached, and the variations in mental ability that may occur during the adult years.

As an illustration of the particular data concerning mental growth, we may take the development of the ability to generalize and to recognize abstract ideas, as indicated by facts drawn from various revisions of the Binet tests. At the age of three and one-half years the average child can identify the *longer* of two sticks or the *larger* of two small spheres. Length and size are abstract ideas, even though very simple ones. At four years the child can point to the longer of two lines drawn on paper, thus using the same concept in a more abstract setting. At four and a half years he can select draw-

ings of faces as *pretty* or not pretty, and at five years he distinguishes *heavy* and light. By the age of six he can tell orally the *difference* between two objects, such as wood and glass, but the ability to describe a *similarity* of two things, as of an apple and a peach, develops a year later at seven. When eight years old, the average child can detect both *similarity and difference* in the same things, as by answering the question, "How are a baseball and an orange alike, and how are they different?" At eleven years he can describe the *similarity of three things*, successfully showing how wool, cotton, and leather are alike. At twelve the child can define some *abstract words* such as "constant," "courage," "charity," or "defend." The average adult can give *differences between abstract words*, such as "poverty and misery," or "character and reputation." It takes a superior adult to note subtle *abstract similarities*, such as that of farming and manufacturing, or to interpret difficult proverbs abstractly. From the longer of two sticks at age three and one-half, to the difference between abstract terms at the adult level, is a long span. It is clear, however, that the ability to do abstract thinking develops gradually throughout most of the growing period. The mental test items that have been enumerated are mileposts along the road of this continuous growth.

The second approach to mental growth, by quantitative measurements of the rate of development, is a complex and difficult matter. To draw a growth chart for height is easy because height is measured in equal units, such as inches, from an absolute zero point. Mental growth units are hard to determine, however, and there is no general agreement as to what constitutes zero of intelligence. Mental age cannot be used for valid growth curves since, by definition, the average child grows to the extent of one year of mental age during each chronological year. This makes mental growth an arbitrarily straight line. Neither can performances in definite functions be used because it is undoubtedly more than twice as hard to remember fourteen digits as to remember seven. What

constitutes "twice as much intelligence" is a much more complex thing to define than what constitutes twice as much height.

From researches that have attempted to determine equal units of mental growth, such as that of Thorndike (1927), some useful approximations have been determined. These studies show that mental growth is *negatively accelerated* throughout the growing period; that is, that the absolute gain

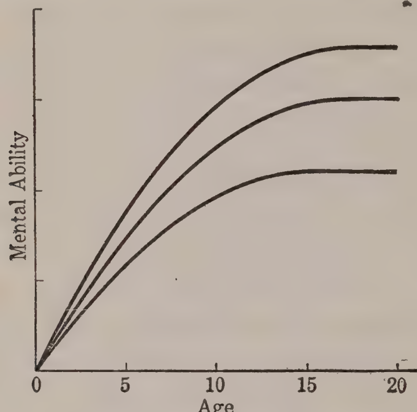


FIG. 110. Mental Growth Curves.

The center line shows the mental development of an average person. The upper line represents the course of development of a person of superior intellect, and the lower line that of a person of inferior intelligence.

at younger ages is greater than that of later years. The center curve in Fig. 110 shows the most probable course of the mental growth of average persons. Further data indicate that superior individuals grow at a more rapid rate throughout the growing period, continue to develop for a longer time, and reach a higher level at maturity. Exactly the reverse of this is true for individuals of dull intellectual ability.

The Constancy of Mental Growth. Any statement concerning the curve of mental growth implies that an individual maintains throughout his life a certain relative rank in intelligence, whether high, average, or low. Like many other statistical facts, this implication is generally true, but not absolutely true. The most satisfactory test of constancy of mental

development employs the intelligence quotient, since this measure may be used to compare the brightness of the same child at successive ages. By retesting children at intervals, the "constancy of the I.Q." can be evaluated. Research studies show that the I.Q. is relatively constant, but not absolutely constant. It is not as invariable as some few mistaken supporters of it have believed, nor as erratic as its most prejudiced critics have contended.

Some actual research results give the clearest picture. Hildreth (1928) reported 1,112 pairs of test and retest results with the 1916 Stanford-Binet test. Individual variations in I.Q. were almost equally divided between upward and downward changes. The average I.Q. of the group changed less than one point from the first test to the second, since the gains made by some children were offset by the losses shown by others. Considering both positive and negative changes together, the variations in I.Q. from one test to the other were:

51%	of children	changed	0 to 4	points
26%	"	"	5 to 9	"
14%	"	"	10 to 14	"
6%	"	"	15 to 19	"
2%	"	"	20 to 24	"
1%	"	"	more than 25 points	

It will be seen that more than half of the children received an I.Q. on the second test within 4 points of that received on the first test. The average absolute change in a child's I.Q., taken without regard to sign, was 6.8 points. Variations of 4 to 7 points do not change the interpretation of an I.Q. substantially. On the other hand, it is to be noted that 1 child in 100 varied 25 points or more upon being retested. The causes of such inconstancies are numerous. Some are due to the inaccuracy of the test as a measuring instrument. Further research studies have shown that the largest apparent changes in I.Q. occur when the first test has been given at a very early age. Ratings determined before the age of six do not conform very closely to those found at later ages, whereas tests given between six years

and maturity show more consistent results. Some variations, however, are possibly due to real changes in the individual's relative intellectual status. On the whole we may conclude that most people grow mentally at a consistent rate. The bright stay bright, the average remain average, and the dull retain their dullness. In less common individual cases, however, some rather large changes in intellectual status may be expected to occur.

Abilities in Maturity and Senescence. It is obvious that mental growth does not go on forever. Just as all persons reach a mature height in early adulthood and do not grow taller thereafter, so also do they reach a level of mental maturity at about the same time. However, there is no one exact age at which intellectual growth ceases, because mental ability is no one single thing. The speed with which people can insert the blocks in a simple form board does not improve appreciably after the age of twelve. In a sense, therefore, the mature level is reached in this function at twelve years, and all average adults remain at the twelve-year level. In the complex task of learning abstract symbols, on the other hand, continuous development up to age twenty-three has been demonstrated. The Binet tests, which give a sort of average of the development of mental functions, show that maturity is reached at the *chronological* age of sixteen. Because of the marked negative acceleration during the later years of growth, the level that the average adult reaches is defined as the *mental* age of fifteen. At this level or above, fifteen is used as the divisor in calculating the I.Q. Thus an adult of any age whose mental age is 17 is above average, which is correctly shown by his I.Q. of $17/15 \times 100 = 113$.

Two misunderstandings about adult mental age must be clarified. First, it is no disgrace for the mental age of the average adult to be only fifteen years. No one is disturbed by the fact that he is no taller than he was at, say, seventeen. His "height age" remains seventeen throughout his life, and his "mental age" has no different significance. Second, the existence

of a mature mental level does *not* mean that persons stop learning at that age. Every individual can learn something every day of his life, and can become more generally competent as he grows older, as common observation shows. The mature mental level of fifteen years means only that the average adult can learn *new* things no better or faster than he could at about fifteen, nor solve new problems of any greater difficulty. In breadth of knowledge, and especially in his skill in his own occupation, the adult can grow greatly, but in speed or altitude of intellect he does not exceed his adolescent level.

It has often been alleged that adults even decrease somewhat in mental ability and become less able to learn new things

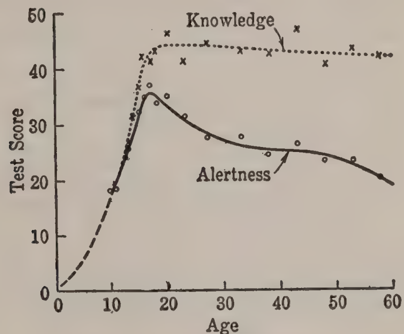


FIG. 111. Age and Ability.

The curve labeled "knowledge" shows scores on a vocabulary test at various ages. This mental ability grows rapidly during childhood and does not deteriorate appreciably during the adult years. The curve labeled "alertness" shows scores on an analogies test. This reaches a maximum at 17 years and drops off with increasing age. Note that 60-year-old persons are still better than 10-year-old children, however. (Composite data after Jones and Conrad. From R. S. Woodworth, *Psychology,* 3rd ed., Henry Holt.)

than when they were in school. Experiments show that this is true of some functions and not of others. A homogeneous New England population was tested, including persons from ten to over sixty years of age (Jones and Conrad, 1933). Fig. 111 shows the results of two of the tests administered. Vocabulary did not deteriorate in the age range tested, but the "analogies test" suffered greatly, the sixty-year-olds doing little better

than the youngsters of ten. The latter test required alertness and flexibility in adapting to unusual material, while the former test, vocabulary, was a function that is constantly used throughout life. It is probable that adaptability to new situations decreases in maturity, but this is offset somewhat by the more effective organization of the knowledge gained through the years. Other experiments have shown that adults can learn as well as children, and often better. Childhood is no "golden age" for learning. The best years are the early adult years, and even an elderly person can learn new material as well as a child of ten.

Many persons retain keen mental ability to extreme old age, but some retrogress in senility and have less intellect than children. Senile mental deterioration is due to definite physiological causes. If the arteries of the brain harden in extreme old age, the neural cells are harmed by undernourishment. This does not occur at any definite age; mentally as well as physiologically it may be said that an elderly person is "as old as his arteries."

The Feeble-minded. Mental tests were first devised for the study of the mentally deficient, and this is still one of their most useful applications. Feeble-mindedness was recognized long before mental tests were prepared, but its nature has been understood better in the light of test results. It is now known that the feeble-minded are not a class apart from other people, but belong to the lower end of a continuous distribution of intellect. There are all degrees of dullness, from the normal individual to the lowest grade of the feeble-minded, and no gap exists between the normal and the deficient.

The feeble-minded are not all alike, but vary considerably among themselves. For convenience, three principal degrees of feeble-mindedness are usually recognized. *Idiots* are the lowest grade, having I.Q.'s under 20, and adult mental ages not exceeding three years. An idiot is extremely helpless mentally. He does not learn to talk, and has to be guarded against common dangers as if he were a little child. The feeble-minded at the next level are known as *imbeciles*; they have I.Q.'s from

20 to 40, and adult mental ages of from four to six years. Imbeciles typically learn to talk, but are incapable of learning to read or write; they can do only the simplest kinds of work. They are utterly incompetent vocationally. In recent years, individuals just above the imbeciles have been designated *morons*. They are usually defined as having I.Q.'s from 40 to 60 or 70, and adult mental ages from six to nine or ten. These persons have limited competence and understanding but can do routine work under supervision. It is doubtful whether all morons should be regarded as feeble-minded, for some of them get along reasonably well if their environments are simple enough. The three divisions of feeble-mindedness are used for convenience only. Each class blends into the adjacent group without any discontinuity. There is no appreciable difference, for instance, between persons whose I.Q.'s are 38 and 42.

The majority of the feeble-minded show no symptoms except their defective intellects. Although physical defects and misshapen features are somewhat more common among the lower feeble-minded than among normals, no diagnosis of feeble-mindedness can be made from a person's appearance. Feeble-minded children cannot be distinguished from normal children by their photographs. Most of the feeble-minded are such only because of the low general efficiency of their nervous systems. A minority of mentally deficient persons suffer from *secondary feeble-mindedness* that is due to other physical causes. There are many such causes, some of which can be treated by medical or surgical procedures. *Cretinism* is one type of secondary feeble-mindedness. It is caused by a serious deficiency of the secretion of the thyroid gland, from birth or from an early age, and can be prevented by the administration of thyroid extract. *Hydrocephalus* is an excessive accumulation of cerebrospinal fluid in the cranium, which causes a large bulging head and direct damage to the brain tissues. Other causes include brain injuries incurred at birth or during the early years of life, severe and prolonged malnutrition, and certain diseases.

The lower grades among the feeble-minded cannot adapt to ordinary social conditions and must be given custodial care throughout their lives. Institutions for the mentally deficient give this care most effectively. All the feeble-minded, except the very lowest idiots, can learn a little. They can be taught to dress and care for themselves and to do very simple work such as caring for the grounds; they usually lead rather happy lives among their fellows. The higher-grade feeble-minded, or borderline cases, can often be returned to ordinary life after a period of training. Morons can be taught simple farming, factory work, or housework under supervision. If desirable traits of personality and character are also inculcated, these individuals can become self-supporting and no longer be a burden to society. The education of the higher-grade feeble-minded requires methods rather different from those used with normal children. Psychologists have contributed much of value to this field.

The Intellectually Gifted. At the opposite extreme of intellect to the feeble-minded are the *gifted.* Although the mentally bright are far more important socially than the mentally dull, they have been studied only recently. Several methods of research have been used, including the detailed study of children who make exceptionally high scores on mental tests, and the examination of biographical accounts of the childhood accomplishments of eminent persons of past generations.

Terman (1925) has reported the most elaborate program of research with gifted children. He and his colleagues identified by means of mental tests approximately one thousand children whose intelligence quotients exceeded 140, and studied their other characteristics. The gifted children, as might be expected, excelled in school achievement almost to the same degree as in intelligence. Eighty-five per cent were accelerated in school, and none were retarded. Superiority in school subjects tended to be general, the typical gifted child excelling in all branches of instruction. These children showed an exceptionally

wide range of interests, including many play interests. They had more hobbies than average children, played a greater variety of games, and read more books. They tended to be popular with their fellows and to do well in sports, common opinion to the contrary notwithstanding. The gifted were better adjusted emotionally than the average, and showed superior character traits. There was even a slight physical superiority, with fewer illnesses and fewer physical defects. This study, then, finds gifted children to have an all-round superiority.

A second study of a portion of the same gifted group was made after an interval of seven years. The boys who were retested retained their superior I.Q.'s, but the girls showed an average drop of 13 points. This may have some bearing on the greater occurrence of eminence among adult males, but the conclusion needs to be verified with more cases. The children had continued their outstanding work in school, and many were doing distinguished work in college. Several of the older ones were already entering professions, and a few gave promise of great achievement in their respective fields of occupation.

Whether the gifted children of today will be the great scientists, authors, and scholars of the future cannot be decided with certainty as yet. Studies of the recorded childhood accomplishments of great men of the past suggest that they were gifted children. Cox (1926) investigated the biographical records of the early years of 301 eminent men and women who lived from the fifteenth to the nineteenth centuries. The group included Darwin, Scott, Goethe, Byron, Mill, Leibnitz, Galton, and others of equal eminence. By noting the ages at which these individuals performed certain intellectual feats in childhood, Cox assigned mental ratings to each. It was estimated that the average I.Q. of this group would have been about 155 to 165, had mental tests been given during their lifetime. It is probable that eminent men were gifted children. Whether our present gifted children will become eminent men remains for future research.

The term "genius" is often applied to persons of extreme excellence in any field. Some historical geniuses have been generally gifted, others have accomplished their work in a limited field, such as music or literature. It is probable that "genius" implies something more than "gifted." In addition to great ability, the genius must have opportunity, capacity for hard work, extremely strong motivation, and singleness of purpose. All these good traits are not often found together, which explains the rarity of genius.

Modern research has definitely refuted a number of unfounded superstitions about the gifted. Mentally bright children are not, on the average, puny, sickly, "nervous," or unsociable. On the contrary, they enjoy better than average strength, health, emotional stability, and social participation. Neither is genius particularly "near to insanity," as a popular misconception holds. Both gifted children and historical geniuses have fewer than the average number of mental disorders, either among themselves or in their families.

Special Abilities

Special abilities, such as mechanical ability, musical talent, and aptitude for the graphic arts, are relatively uncorrelated with general mental ability. Since these special talents cannot be measured by general mental tests, particular testing techniques have been developed for their study.

Mechanical Abilities. The ability to manipulate mechanical devices skillfully is necessary in many walks of life, as in engineering, dentistry, surgery, and science, as well as in the skilled trades. Mechanical ability is not a single or simple entity. Some of its components include strength, precision and speed of movement, the ability to perceive mechanical relationships, and the ability to combine all of these in performing a real task. Speed, the perception of form, and several other simpler components of mechanical skill can be measured by laboratory tests. A widely used test of speed has the subject insert a large number of small disks in the holes of a board as

one task, and turn them over as another task (Fig. 112). Perception of form is measured by requiring the examinee to insert odd-shaped pieces in a form board. In each of these tests

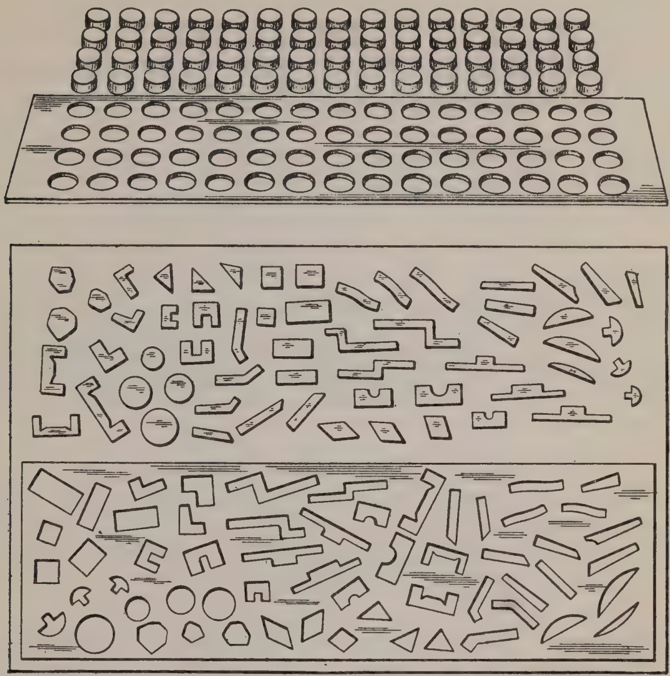


FIG. 112. Tests of Simpler Mechanical Abilities.

At the top is the Minnesota Rate of Manipulation Test. Two tasks are performed with this apparatus. One is to place the disks in the holes from the positions shown in the figure, and the other is to turn over the disks as they lie in the board. At the bottom is the Minnesota Spatial Relations Test. The task is to place the cut-out blocks in their proper places in the board. (Courtesy of the Educational Test Bureau, and of the Marietta Apparatus Co.)

the unit measured is the time taken to complete the standard performance. Persons who are very skillful in the mechanical arts usually excel in tests such as these, but all who do well do not make good mechanics.

As in the testing of general mental ability, complex tests of mechanical aptitude have proved more successful than simple

ones. A widely used test is the Stenquist Assembling Test (Fig. 113). It consists of a box which contains the unassembled parts of ten common mechanical articles which are to be put together. The abilities to see the relationships involved, to understand the operation of the mechanical article, and to assemble it skillfully all function in the test. For particular occupations, such as operating a lathe or running a street car, other

FIG. 113. A Test of Complex Mechanical Ability.

In the Stenquist Assembling Test (Series I), the ten objects to be put together are a cupboard latch, a clothes pin, a paper clip, a safety chain, a bicycle bell, a rubber hose shut-off, a bottle stopper, an electric push button, a lock, and a mouse trap. (Courtesy of C. H. Stoelting Co.)

tests have been devised that resemble the actual tasks. The speed of improvement under uniform instruction is then the measure of the aptitude of an untrained individual.

That mechanical ability is relatively uncorrelated with intelligence does not mean that intelligence is unnecessary for mechanical work. It means that sheer mechanical ability is distributed among persons without much regard to intelligence, some of the verbally stupid being mechanically skillful, as well as some of those who are verbally bright. For distinguished success in a mechanical field both special ability and general intelligence are necessary, but these two components must be measured separately. This is also true of the other fields in which special talents are concerned, including music and art.

Musical Abilities. In music, more than in any other human

activity, the existence of specific talent is clearly recognized. Most great musicians exhibited their ability at a very early age, and sometimes in spite of discouragements and handicaps. In this field also, the greatest amount of valid research has been carried on. The measurement of any complex special ability should begin with an analysis of its parts or aspects. Seashore (1919) gives the following analysis of the traits that constitute musical ability:

I. Musical sensitivity
  A. Simple forms of impression
    1. Sense of pitch
    2. Sense of intensity
    3. Sense of time
    4. Sense of extensity
  B. Complex forms of appreciation
    1. Sense of rhythm
    2. Sense of timbre
    3. Sense of consonance
    4. Sense of volume

II. Musical action
  Natural capacity for skill in accurate and musically expressive production of tones (vocal, instrumental, or both) in:
  1. Control of pitch
  2. Control of intensity
  3. Control of time
  4. Control of rhythm
  5. Control of timbre
  6. Control of volume

III. Musical memory and imagination
  1. Auditory imagery
  2. Motor imagery
  3. Creative imagination
  4. Memory span
  5. Learning power

IV. Musical intellect
  1. Musical free association
  2. Musical power of reflection
  3. General intelligence

V. Musical feeling
  1. Musical taste

2. Emotional reaction to music
3. Emotional self-expression in music

For some of these traits, including the senses of pitch, intensity, time, rhythm, timbre, consonance, and tonal memory, and for some others such as tonal movement, reliable tests have been prepared on phonograph records and have been standardized adequately. Some other factors in musical talent, such as absolute pitch, can be tested under standard conditions with the aid of a piano. Many important qualifications can only be estimated subjectively, especially the higher and more complex abilities, including creative imagination and emotional reaction to music. It is impossible at the present time to make a completely objective inventory of all of an individual's talents in music. The testing of the simpler functions is of great value, however, since they are essential to any satisfactory artistic musical achievement. Without a keen sense of pitch, for example, no one can become a good singer or violinist.

Tests of musical ability have had some use in the public schools. These tests identify youngsters whose capacities are so poor that they cannot hope to learn music and who therefore might as well be excused from the music lesson. On the other hand, the tests discover children of high ability whose musical education should be encouraged.

Abilities in Graphic Arts. Ability in the graphic arts has not been the subject of as much research as that in music, but two useful types of measurement have been devised. A number of *drawing scales* have been constructed for measuring the merits of children's drawings. These measure attainment rather than aptitude, but too fine a distinction must not be made between these two terms. A drawing scale consists of a series of children's drawings of an object which cover a wide range of quality. In constructing a scale, the sample drawings are placed in rank order by a large number of competent judges, and statistical procedures are used to assign a score to each picture. Thus, if 90 per cent of the judges consider drawing A better than B, while only 60 per cent consider B better

than C, then the difference in value between A and B is greater than that between B and C. Kline and Carey (1923) constructed four scales for scoring children's drawings of a house, a rabbit, a tree, and a boy running. To measure drawing ability the subject is called upon to draw one or more of these from memory. His drawing is then compared to the specimens on the scale, and is given the score of the sample that it most nearly equals in quality. These scales are useful in schools, but do not measure high levels of ability. The more comprehensive tests of Knauber (1932) give the subject a number of drawing problems involving immediate reproduction, remote memory, copying, perspective, composition, light and shade, and design. These are scored by comparison with standards of various qualities.

A second type of measure is that of *art judgment* or "appreciation." The person being tested indicates which one of two or more pictures is more pleasing, more satisfying, or more artistic. In the Meier-Seashore Art Judgment Test (1929) there are 125 pairs of pictures. One of each pair is a picture of acknowledged merit, many of which are the less well-known works of great masters. The picture for comparison is the same except for some deliberate change in composition, proportion, emphasis, or other artistic quality that renders it less meritorious. Groups of ordinary students, art students, and art teachers make successively higher average scores on this test, which indicates its validity. Good judgment does not depend entirely on formal training, however, since a few untutored persons make scores as high as those of experts. The authors of this test contend, quite properly, that esthetic judgment, resting upon fine discrimination, feeling, and insight, is basic to achievement in all the graphic and plastic arts. The art judgment test therefore has some value for predicting art aptitude.

Factors Influencing Abilities

Nature and Training. Every ability arises from the interaction of two influences, the natural structure of the individual, and the forces that have acted upon him. It is evident that bio-

logical nature has a considerable effect on all abilities. Animals of different species have different characteristic reactions. Among human beings, some eyes, some ears, and also some nervous systems are better than others. These differences are characteristic of the individual as an organism, and are variously described as structural, constitutional, or inherited.

On the other hand, training has a measurable influence upon all psychological functions, and this effect is very great in some instances. It is obvious that language, the ability to do problems in arithmetic, occupational skills, and many other things are learned. Similarly, it is probable that general intelligence and special talents are affected to some extent by environmental advantages, but the influences are more subtle and difficult to measure. In general, there is no trait that is due to original nature alone or to environment alone. Both contribute to all characteristics.

Further complication is introduced by the fact that constitutional and environmental factors influence each other. How much a person can learn from a given situation depends on his native equipment. Two children do not necessarily receive the same benefit from the same teaching, since the child with greater capacity will learn more. Conversely, training modifies structure. Whenever a person learns and retains, his nervous system has been modified to some extent. The persistence of these neural changes makes it possible to learn a new performance that depends upon a previous one, as when learning the calculus is facilitated by a knowledge of algebra. It is not improbable that general ability may be modified by cultural advantages in just the same way.

Some years ago psychologists endeavored to separate the effects of nature from those of training. This has almost been abandoned as a hopeless task. The two types of influence are so intimately intertwined that it is impossible to state exactly the percentage of nature and the percentage of nurture involved in any one function. Much valuable information has

been accumulated, however, showing the effects of various environmental forces on human abilities.

Normal Constancy of Development. In most cases, a child lives in the same home, has the same cultural contacts, and attends the same school throughout his growing period. At least, he meets with no radical changes with respect to these influences. Such children usually show a good degree of constancy in mental development. The great majority of children whose mental ability is average at the age of six are still average at twelve, and become average adults. Most superior children and most inferior ones likewise maintain their relative ranks with but little variation. Even more definite is the evidence, already referred to, that groups of normal children vary little in *average* I.Q. as they mature. These observations have sometimes been interpreted as proof that intelligence is fixed or hereditary, but such assertions are not based on sound analysis. The constancy of the intelligence quotient under normal conditions of life gives little evidence concerning the relative influences of nature and training. The children remain the same individuals, it is true, but they also remain in the same constant environments. Their constancy, therefore, may be due to innate factors or to environment, or to both. The tests do not settle the question. To probe the effects of environment on intelligence it is necessary to examine persons whose surroundings are not normal or whose circumstances have been changed radically.

Cultural Advantages and Formal Schooling. Substantial evidence concerning the effect of cultural factors upon intelligence may be obtained by measuring persons who seriously lack such advantages. The blind and the deaf-mute often show some mental retardation which is more pronounced if they have not received special education suited to their handicaps. Studies show that the average blind child is retarded to the extent of about 10 points of I.Q., while in aggravated cases the loss may be much greater. Deaf children are even more handicapped because they have great difficulty in learning language. They

show an average I.Q. of about 80, even on performance tests. These deficiencies are due to lack of normal environmental stimulation to mental growth.

Groups of canal-boat and gypsy children in England, whose formal schooling is negligible because they are always on the move, were measured by Gordon (1923). It was found that these children were of low intelligence; but this alone did not prove the influence of environment, since it did not rule out the possibility of a biologically inferior stock. Detailed investigation revealed, however, that the younger children, up to the age of six, were of normal intelligence, with average I.Q.'s of from 90 to 100. Beyond this level the average intelligence quotient declined uniformly with age, the oldest group having an average I.Q. of only 60. In addition to lack of schooling, the other features of the cultural environments of these children were meager, and their parents were illiterate in most instances. This poor environment was sufficient to stimulate mental growth up to the six-year level, but it was inadequate to promote mental development beyond that age. Here again it is shown that environmental stimulation is necessary to intellectual development.

Studies also have been made of identical twins who were separated and reared apart from an early age. Identical twins develop from the same fertilized ovum, and hence have identical heredity. When reared in the same home, such twins are usually alike in intelligence. Of those reared apart, most of the pairs studied had similar intelligence test scores, but they had been brought up in homes that, while different, were on about the same cultural level. However, two pairs of twins had experienced very unlike educational advantages. The I.Q.'s of one pair were 106 and 88, and the other pair 92 and 77. The twin with the superior education had the higher I.Q. in each case. It is dangerous to generalize on so few cases, but even *one* pair of identical twins with widely different intelligences shows that heredity is not the sole cause of mental abil-

ity and that environment may have a considerable effect upon its growth.

The nearest approach to an experimental improvement of environment is found in children who are adopted, presumably into homes better than those of their own parents. Several careful studies of adopted children have been made, one of which will be cited. Freeman (1928) compared the mental test scores of 74 children who had been tested twice, once before adoption and again after an average stay of four years in the foster home. Before adoption the average I.Q. of the group was 91.2, and after adoption 93.7, a gain of 2.5 points. Furthermore, the children who were adopted into homes of higher cultural status gained more than those who moved to homes of less merit. The children adopted at an earlier age also showed a greater gain. These changes show that cultural environment has some power to raise intelligence, but only in limited degree.

The studies showing the effect of cultural environment upon intelligence must not be interpreted as proof that the constitutional nature of the individual has no effect. In countless cases, mentally deficient children are born and reared in homes at an excellent cultural level. Many workers have tried to make feeble-minded children normal or average children gifted, but fruitlessly. Intelligence is probably raised slightly by good cultural advantages, and may be lowered greatly by too great a deficiency of environment. Neither nature alone nor environment alone makes intelligence. Both are necessary.

Urban and Rural Populations. An average difference has been found between city and country children that is of great interest in itself, but which cannot be ascribed wholly to either native or cultural factors. A number of studies show that on linguistic tests, of both the group and Binet types, only about 25 to 30 per cent of rural children exceed the median of city children. All degrees of ability are found in both groups, and the overlapping is great, but the average difference is signifi-

cant (Fig. 114). This difference has also been found in Europe, where children living in Rome, Hamburg, and Paris excelled those in rural regions of the same countries, when tested by non-language tests.

Cultural foundations for these differences are indicated by several facts. Some studies have found a progressive decrease in I.Q. with age among rural children, leading to the same conclusion as in the case of the canal-boat population. Urban children excel rural children on both Binet and performance tests,

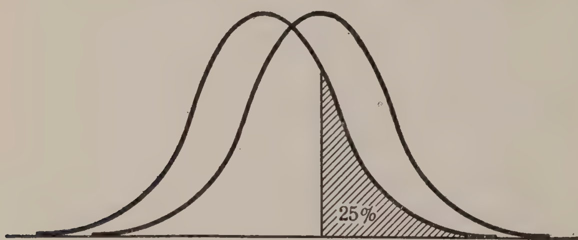


FIG. 114. The Significance of an Average Difference in Ability.

In this figure 25 per cent of the persons in the lower group reach or exceed the average person of the higher group, yet some persons in each group occur at every level of ability. All group differences, such as those between urban and rural children, and between whites and Negroes, are of this type. In no such instance do all persons of one group excel all persons of the other group.

but the difference is greater on the verbal tests than on the non-verbal measures. In fact, on one particular performance test that uses a picture of a country scene (the Healy Mare and Foal Test), a group of Vermont farm children greatly exceeded the norms of city children. Educational opportunities are less available in the country, and some findings indicate a correspondence between the average intelligence test scores of the children and the quality of the schools in various rural areas. Rural children in consolidated schools excel those in one-room schools.

Genetic reasons have also been advanced to account for the differences between rural and urban intelligence scores. Some writers have suggested that the more enterprising persons migrate to the cities, leaving the less able in the country. This

is termed the *selective* factor, and, when operating during two generations, it would cause a drop in the average intelligence of the residual population. It is harder to demonstrate the existence of selective differences than of cultural differences, except by citing specific instances. It may be concluded that both environmental and selective influences operate to bring about the differences observed, but the relative contribution of each cannot be determined exactly.

Sex Differences. Until the advent of mental tests it was almost universally believed that women were generally inferior to men in intellectual ability. Scientific results show that this belief is wholly unfounded. The differences between the average I.Q.'s of boys and girls are negligible, being only from 2 to 4 points at various ages. In the Revised Stanford-Binet Scales, the girls slightly excel the boys at younger ages, while the boys show slightly higher scores when older. The differences are insignificant, however, and may be due to chance errors in selecting the particular boys and girls that were tested. The same standards can be, and are, used for judging both sexes.

Detailed studies show fairly consistent average differences between the sexes in some particular functions, but the overlapping of the sex groups is complete in every case. For example, it has been found that about 40 per cent of girls reach or exceed the median boy in tests of arithmetical reasoning. But there are both boys and girls with every degree of this ability (cf. Fig. 114). Similarly, average superiorities for boys have been found in motor ability, numerical abilities, and achievement in mathematics and science. The average girl excels in linguistic and memorizing abilities, and in school marks for handwriting, literature, and languages. On the average, girls are more suggestible than boys; boys have a larger number of speech defects. Differences in interests and in personality traits are more pronounced than are differences in abilities.

It is probable that cultural factors account for a large part

of the observed sex differences. In our civilization boys are encouraged to engage in motor activities and girls are often discouraged. A tradition excuses girls from the necessity of accomplishment in mathematics and science, and this reduces their motivation in these subjects. Such environmental pressures are sufficiently intense and widespread to cause the differences observed. Scientific research, on the whole, shows that sex differences are not nearly as great as is commonly assumed, and that they may be due entirely to the social molds forced upon boys and girls by convention. Certainly there is no justification whatsoever for the old superstition that men are guided more by "reason" and women by "feeling."

Races and Nationalities. Since the United States contains large numbers of persons of three races—the white, Negro, and American Indian—the interest in racial differences is considerable. Numerous measurements of racial groups have been made, but the results are difficult to interpret. The great effect of cultural factors upon intelligence has already been shown in several instances. Since the racial groups are far from being alike in cultural environments, it is impossible to determine what part of the observed differences is due to the influence of race alone. In measurements of the general mental ability of whites and Negroes, about 25 per cent of the latter are found to excel the white median (cf. Fig. 114). About the same result has been found in testing white and colored infants, school children, and the adult draft of the war in 1918. This blanket conclusion, however, hides many facts of great importance. On the "Army Alpha" group mental test, the average score of northern Negroes was 38.6, and of southern Negroes 12.4, as compared to the white norm of 58.9. The same degree of difference was found between southern whites and northern whites, however. The white men from Connecticut, for example, averaged 73.6 points, while the Georgia whites had an average score of 42.2. In fact, the Negroes from some northern states excelled the

whites from some southern states, as is seen by comparing the score of 49.5 made by colored men from Ohio with the 42.2 for the white men from Georgia.

Two hypotheses have been advanced to account for the racial differences described. One holds that *selective migration* has attracted the more intelligent Negroes to the north. In view of the differences among whites as well as Negroes from the various states, the alternative explanation of *differences in cultural advantages* seems to be more probable. There may still be some innate racial differences, but they are surely not large and they are almost entirely hidden by the superimposed cultural variations.

Differences among various nationality groups in the United States also exist, but they too have been shown to be largely cultural. The Army Alpha ranked the average scores of the natives of several countries in the following order: British, Dutch, German, native American whites, Swedish, Irish, Austrian, Greek, Russian, Italian, and Polish. It has since been pointed out that this list represents a scale of educational opportunity. The foreign countries ranking high represent the older immigrations, and their nationals had been better educated in their native lands. The lower groups are of more recent immigrations and have been less in contact with the American culture and schooling upon which the tests were constructed. On nonlanguage tests the differences among the national groups were much smaller.

A few attempts have been made to measure children of various nationalities in their own countries by means of nonlanguage tests. Klineberg (1928) found small differences between various "Nordic," "Mediterranean," and "Alpine" groups in Europe, and not consistent ones. Some of the Mediterranean groups excelled some of the Nordics, and no consistent racial-group superiority was noted. The same investigation, however, found large differences between urban and rural groups in all countries. Porteus (1931) found that Australian aborigines were somewhat inferior on the white

men's performance tests. He constructed a test of matching photographs of footprints, however, on which these primitive people did quite as well as whites. When given a task comprehended by their culture, the inferiority disappeared entirely.

Most psychologists have reached the conclusion that there are no measures that are suitable for comparing racial and national groups. The present tests are too much influenced by the extent to which the foreign groups have assimilated the culture of the country for which the tests were constructed.

Chapter XV

PERSONALITY AND CHARACTER

Personality Traits and Their Measurement

How Personality Is Shown in Conduct. The term *personality* is widely used in popular speech, and the qualities to which it refers are highly regarded. Most people think of personality as a rather vague entity that an individual possesses or does not possess. This is a misconception based on insufficiency of observation and information. The personality that the psychologist studies is the same phenomenon as that of which the layman speaks, but the psychologist's approach is more detailed and precise because of careful analysis and measurement.

An individual's personality is evaluated by observing his usual ways of adjusting to the situations that life presents. A meeting of a committee, for example, will reveal the personalities of the individuals that compose it. One person is aggressive and dictatorial, and tries to settle all matters himself without regard for the others. Another straddles every issue cautiously, not committing himself until he knows what the others believe. One individual may be oversensitive and feel a personal slight if anyone questions his opinions. One member may see the other's points of view fair-mindedly, whereas another refuses to be stirred from his preconceived ideas. The situation thus brings out the *typical reactions* of the individuals concerned. Each typical form of behavior that can be designated by a descriptive term is a *trait of personality.* Among the traits shown by the members of this committee are dominance, compliance, sensitiveness, fair-mindedness, and prejudice.

A trait of personality is a descriptive term. It is not something that an individual possesses, but a way in which he behaves. In common speech it is often said that a person "has self-confidence," and psychologists may use this expression as a convenient shorthand. What is really meant, however, is that he acts in a self-confident manner. The criterion of a personality trait is behavior, and no trait exists except as the individual shows it in his actions. It is also clear that a personality trait is not an all-or-none affair. It is incorrect to say that a person possesses or does not possess a given characteristic. All personality traits vary continuously in degree. Individuals cannot be classified as being exclusively aggressive or submissive. Most persons are between these extremes, and all stages of deviation from the average can be found. Personality traits, like abilities, are distributed as continuous variables.

Although all situations that are encountered frequently call forth typical responses, the reactions referred to as personality traits are usually elicited in *social situations*. Much of human life is spent in contact with people. The popular view of personality emphasizes its social significance because it is related to the art of getting along with persons, and psychology affirms this opinion. Also, personality refers to *consistent* behavior rather than to that which is temporary or occasional. Every person is aggressive in some situations and submissive in other circumstances. His manifestation of this personality trait has a certain amount of constancy, however. In most situations he will carry out some usual or habitual degree of this response. In the measurement of a personality trait the individual's average or consistent behavior is investigated, rather than the infrequent exceptions. Personality traits, then, are the individual's typical integrated ways of reacting to social situations.

Measuring Personality Traits. In everyday life, traits of personality are estimated by *observing* the individual directly, by *asking others* about him, or by *questioning* him about what he would do in certain typical situations. The psychological

methods for measuring personality follow these time-honored procedures, but they are more precise and refined. The improved techniques for measuring personality are similar in principle to those employed in the measurement of ability. A uniform and controlled situation is presented to each person who is to be measured. The subject makes a definite response that can be recorded quantitatively and analyzed statistically. The measures of personality traits that are in use today are far from perfect, but they are much superior to the casual estimates that were formerly made.

One of the techniques used for psychological research in personality is the *rating scale*. This is a logical development

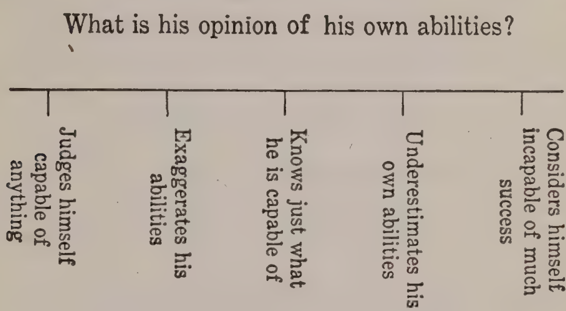


FIG. 115. An Item of a Rating Scale.

The rater answers the question by placing a check mark over one of the descriptions or between two of them. The quantitative score is determined by the distance of the check mark from one end of the line.

of the conventional method of "asking others," such as is commonly used in the letter of recommendation. The rating scale puts a definite question to the rater, and guides him to reply in a manner conducive to uniformity and numerical treatment. For example, an item on a rating scale is shown in Fig. 115. The rater answers the questions by placing a check mark at some point along the horizontal line. He may place it directly over one of the descriptive phrases, or between two of them. The rating is reduced to a quantitative score by measuring the distance of the check mark from one end of the

line. A single rating possesses little reliability, since it may be influenced by inadequate observation or by prejudice, but the average of several ratings made independently by competent judges has some value. Another way to increase the significance of a rating scale is to use a number of questions about the same trait and to average the scores.

The scientific development of the method of estimating personality traits by questioning the subject directly has resulted in the *personality questionnaire*. This is the most widely used method for measuring typical social reactions at the present time. In order to ask exactly the same questions of all persons, the stimuli are presented in the form of printed questions. The possible responses are limited to a few alternative answers, usually "yes," "no," or "doubtful." Some questions that relate to the same general trait that was just used in the illustration of a rating scale are as follows:

1. Do you like to take responsibility?	Yes	No
2. Does it bother you to have people watch you work? . .	Yes	No
3. When someone criticizes you, do you feel that you are to blame?	Yes	No
4. Does the average conversation usually confirm your ideas?	Yes	No
5. Are you self-confident?	Yes	No

A questionnaire usually contains one hundred to two hundred questions centering around the trait that is to be measured. The score is the number of significant answers. In the questions above, it is not difficult to see self-assurance indicated by an answer of "yes" for some and "no" for others. A uniform key is used in scoring, and the numerical results are tabulated. Scores are usually expressed in terms of the individual's percentile rank in an appropriately defined group, such as adult women or college freshmen. Questionnaires must be given under conditions that enlist the confidence and cooperation of the subjects. Obviously, it is possible for the answers to be untruthful and therefore to misrepresent the real personality traits. It is not difficult to secure sincere an-

swers from most persons, however, if the questionnaire is presented correctly.

The most valid popular method for estimating personality is by observation. But ordinary observation is ineffective because various individuals are rarely observed under exactly the same conditions. Furthermore, it is hampered by poor recall of what was observed, by prejudice, and by a tendency to generalize from insufficient material. Two psychological techniques that represent improvements over common observation are *controlled observation* and the *test.*

Controlled observation of personality traits can be made in some instances. In one experiment children of various ages were shown a piece of candy, which was then placed in a box fastened by several latches that were difficult to undo. Individual differences were carefully observed and recorded in detail, indicating the child's tendencies to persevere or give up, to work independently or appeal for adult assistance, and to remain calm or become enraged. In another experiment the social contacts of children on a playground were carefully recorded by observers who were hidden. Even among two-year-olds considerable individual differences in the tendency to play cooperatively or alone were noticed. Controlled observation is a laboratory technique, necessary for research, but of limited use for the practical measurement of personality differences.

Tests have been used chiefly for the measurement of typical reactions that are usually classified as character, such as honesty or cooperativeness. A simple test of honesty in one particular situation may be conducted by having students mark their own objective quiz papers while the examiner reads the answers. Unknown to the subjects, these tests have already been scored, without any marks being made on the papers. Cheating is easily detected by comparing the impartially scored and the self-determined marks. Such experiments cannot be made when the subjects know that their honesty is being tested. Paradoxically, the examiner must deceive the

subjects in order to measure their honesty! Character tests are not used for detective or punitive purposes, but are valuable for research. Some of the results are stated in another section of this chapter.

Some Traits of Personality

Many traits or components of personality have been designated by names and measured with rating scales, questionnaires, or tests. The number of such traits is limited only by the number of human habits and by the ingenuity of psychologists to name them. Therefore, few personality traits are ultimate, fundamental, or entirely independent of one another. Self-confidence, aggressiveness, dominance and independence have all been measured, for example, but they obviously have much in common. Each represents a mixed segment of the total personality, but one of practical value in sizing up people.

Introversion-extraversion. One of the first traits measured by psychologists was introversion-extraversion. At one extreme of this characteristic is the extravert, or the person who is objectively oriented, is governed by social considerations, and likes to be with people and to deal with concrete things. On the other hand, the introvert is subjective, is governed by absolute standards or principles, is not a good mixer, and prefers to deal with ideas and abstract problems. At first, the hypothesis was proposed that all persons are either extraverts or introverts. This was disproved when measurements were made. On a questionnaire of one hundred items, very few people will answer all the questions in the introvert or extravert manner. Most have an average degree of introversion-extraversion; a few are farther from the middle of the distribution. Graphs of the results of an introversion-extraversion questionnaire resemble those of the distribution of abilities.

Since the introvert-extravert trait distinguishes between the "man of thought" and the "man of action," suggestions concerning the choice of an occupation are sometimes made in terms of this measure. The scholar, for example, is said to be

more introvert, while the salesman tends to be toward the extraverted end of the distribution. These suggestions contain some truth, but other qualifications may be much more important than this personality trait in determining vocational success. Measurements of office workers and salesmen show an average difference in the expected direction, but the groups overlap greatly, giving no clear separation. Research results show that more introverted students receive better school grades than do the extraverts, although the intelligence of the two groups is equal. This finding reflects the bookish interest of the introverts. On questionnaires, women score more introvertedly than men to such an extent that different standards have to be used for the sexes. It is probable that the sex difference is due to training and environmental pressure.

Ascendance-submission. Another important trait of personality has been defined as the disposition of an individual to dominate his fellows in various face-to-face relationships in everyday life, or to be dominated by them. This trait is measured by the Ascendance-Submission Reaction Study by Allport (1928). The A-S Reaction Study describes various everyday situations and asks the subject to indicate his usual reaction by checking one of several alternatives. The form for men describes situations that might arise at athletic contests, receptions, lectures, encounters with salesmen, and social gatherings. The form for women has many of the same items, but eliminates some that are more typically masculine and substitutes situations arising in beauty shops and stores. The items were selected and weighted scores were assigned to the various answers, by trying out the tests on college students who had been rated in ascendance-submission by their fellows. This selective procedure increases the validity with which the test measures ascendance-submission.

Experimental results show that executives are more ascendant than students or laborers. The trait is not related to age, physical measurements, or intelligence, but is somewhat allied to extraversion. Ascendance-submission is not an in-

flexible or native characteristic of the individual, but is subject to modification. In one experiment, the most submissive members of a group of 400 college students were given intensive personal coaching for six months, which resulted in a marked alteration of the characteristic. Excessive ascendance can also be changed, but not so easily. Except possibly for executive or sales work, ascendance is not necessarily a more desirable trait than submissiveness. Submissive persons may possess many other good qualities, may be well adjusted and happy, and are usually easier to get along with socially.

Worries. A personality characteristic of a somewhat different nature is the tendency to worry over many things. One way in which this trait has been investigated is by the Pressey X-O (Cross-Out) Test (1921). A part of this questionnaire consists of a list of 125 things about which persons might worry, such as: temper; disease; pain; money; awkwardness. The subjects are instructed to draw a line through each word that represents something about which they have ever worried, or felt nervous or anxious. The score is the number of words crossed out. The number of worries revealed decreases quite uniformly from an average of about 47 in the seventh grade to about 35 at the end of college. There are no marked differences between boys and girls. Individual differences are conspicuous. In one study of college students the individual at the top of the middle half of the group showed 22 more worries than the individual at the bottom of the middle half.

Self-confidence and Sociability. Although many personality traits overlap to a considerable extent, statistical methods can be used to determine traits that are independent of one another. Such a study was made by Flanagan (1935) upon a personality questionnaire of 125 items that had been constructed previously by Bernreuter (1931). By a complicated statistical analysis, two groups of questions were separated, so that the score obtained from one set was quite independent of the other. The independence of two traits means that an individual with a given score in one trait may have any score,

high or low, in the other. By examining the questions that designated the two independent traits, Flanagan named them *self-confidence* and *sociability*. It is probably a better scientific procedure to identify a coherent trait first and to name it afterward, than to follow the more usual method of first naming a trait and then seeking questions that define it. Self-confidence is the tendency to be wholesomely sure of oneself and to adjust readily to new problems. Its opposite is characterized by painful self-consciousness and feelings of inadequacy. Sociability is a preference for group participation and gregarious activity, as contrasted with solitude and self-sufficiency.

The definitions of self-confidence and sociability are helpful in understanding the relationships between certain other personality traits. Extraversion was found to be not a simple unit trait, but to consist largely of self-confidence with an appreciable admixture of sociability. This complexity introduces an error in the measurement of introversion-extraversion.

Quality of Adjustments. Several questionnaires have endeavored to measure the general quality of an individual's social adjustments. These are called measures of "emotional instability" or of "neurotic tendency," although they are often disguised by such general names as "personal data sheet" or "personality schedule." The first questionnaire of this type was constructed by R. S. Woodworth for use with the army draft of 1918. A list of 200 common symptoms of social and individual maladjustment was first gathered from case studies. The questions concerned physical symptoms, social adjustments, fears, worries, unhappiness, fantasies, and other difficulties of conduct. The questionnaire was tried out on normal persons, and symptoms that occurred so frequently as to be of little significance were eliminated. The resulting series of questions was found to distinguish between normal individuals and those who had known difficulties of social adjustment. A later questionnaire for the same purpose was devised by Thurstone (1930) and contained items such as the following:

yes no ? As a child did you like to play alone?
yes no ? Do you usually control your temper?
yes no ? Do you get stage fright?
yes no ? Have your relationships with your mother always been pleasant?
yes no ? Do you feel that life is a great burden?
yes no ? Have you ever had the habit of stuttering?
yes no ? Does your heart sometimes sound in your ears so that you cannot sleep?
yes no ? Do you have difficulty in starting conversation with a stranger?
yes no ? Do you worry too long over humiliating experiences?
yes no ? Are your daydreams about improbable occurrences?

General adjustment questionnaires do not measure specific traits of personality, but are an omnibus survey of the entire effectiveness of social behavior. They have proved useful for selecting students who are in need of psychological counseling. Some results obtained from administering these questionnaires are of interest. The average college woman acknowledges about 17 per cent more symptoms of maladjustment than does the average college man. The average fraternity man is revealed as slightly better adjusted than the average non-fraternity man, probably because of social selection. There are no significant differences between Jewish and non-Jewish students in this respect. No relationship between quality of adjustment and intelligence test scores exists, but the more poorly socially adjusted students get slightly higher college grades.

Several attempts have been made to distinguish the various fields of experience in which personality traits are generally good or poor. The Adjustment Inventory by Bell (1934) is scored in terms of *health adjustment* ("Do you have many headaches?"), *home adjustment* ("Have you frequently quarreled with your brothers or sisters?"), *social adjustment* ("Are you troubled with shyness?"), and *emotional adjustment* ("Are you easily moved to tears?"). This blank contains a large number of questions divided among these four

classifications. With a similar purpose, the Student Questionnaire of Symonds and Block (1932) analyzes the pupil's adjustments to the curriculum, the social life of the school, the administration, the teachers, the other pupils, and the home and family. Aside from research, the object of a personality questionnaire is always to discover persons who need help, and to collect reliable information about them. Questionnaires whose scores can be analyzed in terms of various areas of adjustment are more valuable for practical purposes than are questionnaires whose results are expressed as a single measure.

How Personality Traits Develop. Personality traits are not inherent characteristics of an individual, but are the habits that he acquires from his social experiences. The principles governing the acquisition of habits of conduct and social adjustment are the same as those underlying any other type of learning. Personality habits are brought about chiefly by trial and error learning. The aggressive person is one who has found that he can satisfy his motives and gain his ends by direct action. The submissive person has hit upon the alternative solution of getting along with people by following the leadership of others. Childhood is the most important period for the acquisition of traits of personality, but modifications of greater or lesser degree continue throughout life.

The factors influencing the development of personality traits are made more clear by examining particular cases. Let us consider the making of a hypothetical "introvert." Suppose that a child is reared in a household in which there are no other children, and that his outside contacts with other youngsters are few. This will make him tend toward a lack of sociability with others of his own age, and a preference for playing by himself. If the parents' interests are in reading and quiet intellectual amusements rather than in social activities or sports, the child will follow their example. Perhaps, because of lack of motivation and practice, he will never become skillful in large-muscle activities such as ball-playing that are social assets among groups of boys. He may have a number

of childhood illnesses that further prevent social contacts and promote solitary play and daydreaming. If his early experiences in group participation are unsuccessful, and if other children bully him or taunt him because of some characteristic, the child may reinforce his habits of social seclusiveness. Not all these circumstances will operate in every instance, but the illustration shows how physique, health, skill, parental example, and chance conditions of success or failure may make the individual into an "introvert." The development of other traits of personality could be described by similar case histories. The number of influences that are involved in the development of traits verify the definition of personality as the integrated operation of all the characteristics of an individual.

Emotional development is especially important in the formation of traits of personality. Most children react to frustration by having tantrums of rage on some occasions, but most adults have learned not to resort to this overviolent emotional expression. If tantrums have been successful in getting an individual what he wants, and if circumstances have prevented the unlearning of this reaction, it may be carried into the adult years. Such a person must always have his own way, and is very unhappy if obstructed. Although this tendency does not correspond exactly to any of the personality traits that have been named and described, it is an important aspect of the individual's typical social behavior. Excessive fear, arising from many possible causes in childhood, may create a shy and overcautious personality. Too much pampering, or stimulation of the "love" type, often produces a person who expects others to give him special consideration and sympathy, and who therefore is oversensitive to slights and humiliations.

Although habit formation accounts for most of the variations in traits of personality, certain physiological factors also have some influence. An excessive secretion of the thyroid gland, for example, causes restlessness and overactivity. An undersecretion of this gland produces the opposite effects of

lethargy, slowness, and fatigability. A serious disturbance of the sugar metabolism of the body, as in diabetes, may cause depression and confusion. In individual cases it is necessary to consider these physiological disturbances in relation to personality. A given variation in personality may result from glandular factors in one case, and from purely psychological conditions of habit in another.

Traits of personality are usually rather permanent. Often, upon studying the history of an individual, one can detect the same typical habits of social reaction at the ages of five, twenty, and fifty years. The common permanence of personality traits does not, however, indicate that they cannot be changed. Personal habits usually remain fixed because they are learned so early and practiced so much. Other habits, such as those used in arithmetic, are practiced only occasionally, but one's personality operates during most of the hours of waking life. For an adult to modify a personality trait is not impossible, but it is very difficult. Before any change can take place, the individual has to be clearly aware of his shortcoming, and strongly motivated to acquire a different characteristic. He must face the difficulty without making excuses for it, and must not be overwhelmed by a fear that the desired result is unattainable. It is necessary to practice the new habit in every possible situation, never to let an exception occur, and to take an inventory from time to time to see how nearly the goal is being reached. By these procedures worth-while improvements can be achieved in such traits as sociability, courtesy, or ascendance. Miracles are not to be expected, for it may take years of practice to undo a habit that was years in forming.

Interests and Attitudes

Vocational Interests. No sharp lines can be drawn between personality traits, interests, and attitudes; and the definitions of these terms are somewhat arbitrary. By an interest is usually meant an activity that a person prefers to do, that

he will not avoid, and that he will choose in preference to other things. Vocational interests, the patterns of preference that lead to the choice of an occupation, have received a large share of attention. It has long been recognized that the selection of an occupation and the satisfaction experienced in its pursuit depend more on interests than abilities. Men in varied occupations, such as law and engineering, display about the same range of general ability, but differ considerably in interest patterns. Only recently have valid measures of interests been made.

Occupational interests have been tested quite satisfactorily by the Vocational Interest Blank of E. K. Strong. This questionnaire consists of 400 items to which the examinee responds for the most part only by stating whether he likes, is indifferent to, or dislikes the thing named. The items include names of occupations, amusements, school subjects, activities, peculiarities of people, order of preference of activities, choice between pairs of activities, and a rating of personal traits. The use of the blank depends upon the experimental discovery that successful persons engaged in various occupations can be distinguished quite sharply by their interests. Engineers show one typical pattern of responses to the interest blank, while lawyers, salesmen, teachers, and office workers each respond in quite different ways. The groups named overlap very little. Of course, considerable similarity of interest is shown by closely allied occupations such as medicine and dentistry. For each occupation a key is constructed experimentally. If, for example, a large proportion of practicing engineers indicate "dislike" for the item "Actor," then dislike for being an actor is a partial symptom of engineering interest. One such item has no value, but when the procedure is applied to over four hundred varied questions, the result is quite valid. Scoring keys are constructed in a similar manner for other occupations, of which more than thirty have been investigated up to the present time. A similar blank has been prepared for

women, which can be scored according to the interests of eighteen occupations that women pursue.

The vocational interest scores of college students are a useful guide to the occupations that they might enter or continue to follow. One group which had taken the interest blank while in college was studied for five years after graduation. The men who continued in an occupation had higher interests in it than in any other one. Graduates who changed their occupations showed in their earlier test a high interest for the work to which they later changed. The interest indications of the blank are much more valid in many instances than is the person's expressed preference. Thus in one case, a young man who disliked engineering thought that he should study medicine. The interest blank, however, showed that he was as low in physician interest as in engineering, but that he had high interests in mercantile occupations. When these facts were presented to him, he admitted that he had not given much thought to medical school requirements. He particularly disliked chemistry, but had not realized how much this subject entered into the preparation of a physician. In the end he made a success in a business position. The guidance provided by the interest blank probably saved him from an unsuccessful and unhappy attempt to study in a medical school.

Other Measures of Interests. Scales have been constructed for measuring maturity of interest by comparing the preferences of fifteen-year-old boys with those of adult men. There is also a scale for masculinity-femininity of interest, since men and women have been found to differ considerably in interest patterns, although some persons of each sex deviate in the direction of the other. Techniques similar to those used in the occupational interest blank have been employed to distinguish interest in technical, academic, and business courses in high schools. The experimental nature of all interest blanks must be emphasized. In no case does anyone decide what the interests of a group "ought to be." The measurement is always

of the declared interests of a known group, to which other people are compared.

A different attack on human interests has been made in the questionnaire called "A Study of Values" by Allport and Vernon (1931). This study defines six fields of value or interest, namely, the theoretical, economic, esthetic, social, political, and religious. The test consists of 45 described situations in each of which the subject must choose an alternative that differentiates between two types of value, or else must rank several alternatives in the order of their importance. As usual, average sex differences are found. Men rate the theoretical, economic, and political values higher, while women excel in esthetic, social, and religious values. Even more striking are the results of groups preparing for various careers. Students of engineering scored highest in the theoretical and economic values; students of business in the economic and political; students of language and literature in the esthetic; and theological students in the religious and social. Further evidence also suggests that an individual's everyday attitudes toward his clothes, toward the conditions in life that will satisfy him, and toward his conception of the "ideal" person are all greatly influenced by the fundamental values measured in this study.

Attitudes. Attitudes are very closely related to interests, but, in general, they are concerned with broader issues. Thus we speak of a person's attitude toward war, toward religion, toward Negroes, or toward education. In each instance attitudes may vary from enthusiastic acceptance, through indifference, to strong antagonism. Literally an attitude means a posture, and an objective concept of attitude pictures the individual as approaching the stimulus, or retreating from it, or remaining unmoved.

Scales for measuring a number of attitudes have been constructed by L. L. Thurstone. Each scale consists of a list of statements about the issue in question, and the examinee checks the statements with which he agrees. Ten selected items from Thurstone's Scale for Measuring Attitude Toward the Movies are given.

(1.5) The movies occupy time that should be spent in more wholesome recreation.
(1.3) I am tired of the movies; I have seen too many poor ones.
(4.5) The movies are the best civilizing device ever developed.
(0.2) Movies are the most important cause of crime.
(2.7) Movies are all right, but a few of them give the rest a bad name.
(2.6) I like to see movies once in a while, but they do disappoint you sometimes.
(2.9) I think the movies are fairly interesting.
(3.9) The movies are good, clean entertainment.
(3.9) Movies increase one's appreciation of beauty.
(3.4) A movie once in a while is a good thing for everybody.

Each statement has a scale value, as shown at the left of each item, that was determined by a statistical treatment of many judgments of the attitude shown by it. The scale values vary from a low figure for complete rejection to a high figure for complete acceptance. The average of the scale values of the statements checked by the examinee measures his attitude.

Attitude scales have been used to determine the extent to which an attitude may be influenced by various experiences. In one study, a group of high school students responded to a scale of attitude toward war, and soon afterward were shown a motion picture dealing with war. Their attitudes were again measured, and the results revealed that the film had caused a significant change in their attitudes toward war which persisted for several months. In another research, the attitudes of pupils toward a nationality group were found to have improved by a sympathetic study of the history, customs, and literature of that nation.

Fair-mindedness. A general attitude that has provoked some significant research is the trait of fair-mindedness. Fair-mindedness is defined as the ability to consider facts and arguments impartially, regardless of which side of a question they support, and to avoid extreme and unjustified conclusions. It is the opposite of prejudice. The test of fair-mindedness constructed by G. B. Watson (1925) is presented in disguise as "a survey of public opinion," so that the subjects do not know that their prejudices are being measured. The test contains a number of

types of questions. The "degree of truth" test lists 53 controversial statements on social, economic, and religious issues. The subject indicates whether he considers each statement "utterly and unqualifiedly true," "probably true," "uncertain," "probably false," or "utterly and unqualifiedly false." None of the statements justifies the extreme character of the first and last judgments. The prejudice score, therefore, is the number of extreme beliefs to which the examinee subscribes. The same technique is used in a "judgment test," the score being based on unjustified judgments of "all" or "none." Another part is called the "moral judgment test"; this is scored by observing the responses to carefully concealed pairs of questions. If the subject approves a certain deed during the French revolution of 1789, but disapproves the very same deed in the Russian revolution of 1917, he shows prejudice. Mere differences of opinion do not enter into the measurement, for the subject may disapprove of both acts or approve of both without any lack of fair-mindedness. In addition to a general fair-mindedness score, the test measures prejudice for or against several particular movements, institutions, or beliefs, as may be seen in the accompanying figures.

Insight into the nature and origins of fair-mindedness can be obtained by examining the test results for certain individuals in relation to their everyday conduct. Fig. 116 is the "profile" of a man of marked prejudices. Here he can see himself objectively as he actually is. An acquaintance writes: "I consider this man one of the most prejudiced individuals I have ever known. He is so much of a fundamentalist that he gleefully condemns to the nethermost hell any person who suggests that heaven is not up above the clouds, a real, existing place. He has been a leader in finance, connected with one of the greatest banking institutions of the country. He said to me at one time, 'I should like to see every socialist with a millstone around his neck thrown into the deepest part of the ocean.' "

Fig. 117 shows the profile of a woman unusually free from prejudices. She writes: "Eight years of comparative leisure in

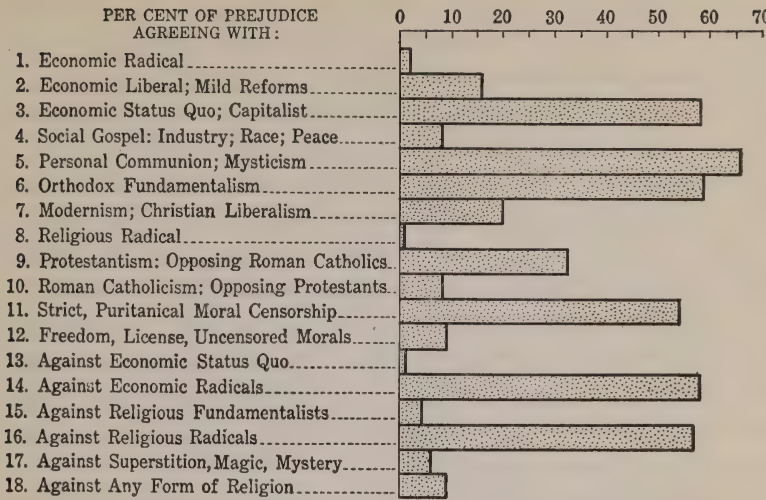


FIG. 116. "Profile" of a Very Prejudiced Individual.

The amount of prejudice is shown by the lengths of the bars. (From G. B. Watson, *The Measurement of Fair-Mindedness,* Teachers College, Columbia University, publishers.)

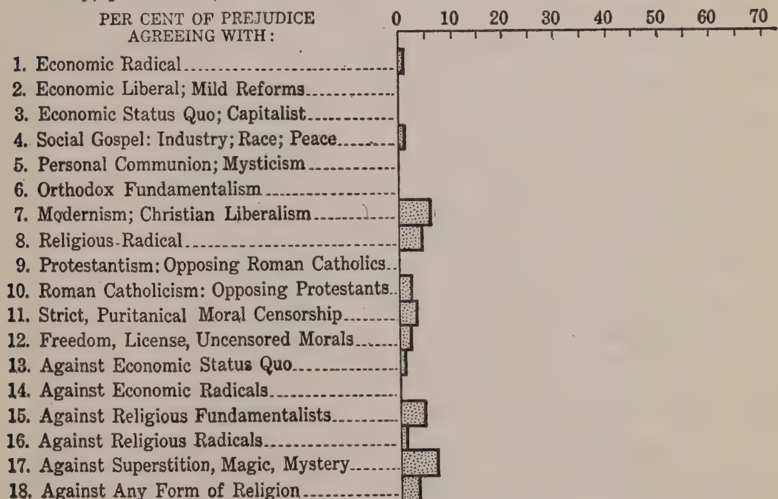


FIG. 117. "Profile" of a Very Fair-minded Individual.

This woman has very little prejudice on any issue. (From G. B. Watson, *The Measurement of Fair-Mindedness,* Teachers College, Columbia University, publishers.)

a cosmopolitan city, abroad, gave me the advantage of a wide variety of friends of different races, classes, beliefs, and interests, from every part of the world. The complexity of social conditions and the genuineness of widely diverse points of view came home to me vividly. With such a nature, schooling, and experience is it strange that I should reserve decisions, reconsider all kinds of arguments, and make all possible allowances, in such a way as to give me a low score on this test? The 'All' or 'No' response is utterly foreign to me. Whatever my own opinions, such matters are phenomena for study rather than cases for action on my part; the behavior of persons concerned is to me a matter for interpretation rather than simple praise or blame, for study into sources, and the enormous complexity of social causes and results."[1]

The Development of Attitudes. Studies of attitudes and interests reveal many of the common irrationalities and inconsistences of human nature. People seldom govern their social affairs, choose their occupations or make their judgments of political, moral, or religious matters entirely by the use of intellect or reasoning. Issues are most often judged, not on their own merits, but in keeping with a person's attitudes, prejudices, and interests. In these important matters people rarely begin with the facts and draw conclusions; they begin with preconceived conclusions and marshal the facts to fit their purposes. Because of the great significance of attitudes in everyday life, it is important to investigate their origins.

Attitudes and interests are learned, not native. Every person acquires his typical attitudes as a result of his own experiences. Psychological study has revealed three chief factors that mold attitudes and interests. One of these elements, which may be mentioned first because it is the most approximately rational, is *accumulated experience.* It is probable that many of our most sensible and worth-while attitudes arise from

[1] G. B. Watson, *The Measurement of Fair-Mindedness,* New York: Teachers College, Columbia University, 1925, pp. 52, 63.

countless minor experiences that become integrated into a habitual point of view. Thus a professor's opinion of student honesty, or a commuter's attitude toward the reliability of the trolley schedule may arise from many direct observations. In the formation of these attitudes the incidental learning gained from personal experience is usually more effective than the direct or intentional teaching offered by schools, advertising campaigns or parental admonitions.

A second important creator of attitudes is the *dramatic incident*. One single experience, if it is intense enough, may form an attitude that will endure for a lifetime. This is especially likely to occur if the individual has few opportunities to encounter the situation toward which the attitude has been formed. One unpleasant experience with a Mexican, for example, may cause a prejudice against all persons of that nationality, which is hard to combat without further and more extensive contacts with Mexicans. A first-hand account of this tendency is cited.

The only Frenchmen most of us in —— had ever met as children were teachers. One of these had been a journalist and seemed to be in a constant state of excitement over one thing or another. The other was a heavy drinker. At the same time we also had at school a very popular old science teacher who had been fighting in the war of 1870 on the German side and who on the least provocation would narrate his war experiences, probably with more dramatic skill than truthfulness. At any rate, he painted the French people unfavorably in such a way that the two Frenchmen we knew seemed to confirm the diagnosis, with the result that their presence in the community only confirmed our unfavorable, and, as we later learned, untrue picture of the French people.

Favorable as well as unfavorable attitudes may be formed by the same process, as the following description shows.

The most popular of all the students at a summer camp was a Filipino. He was full of fun and amusing tricks. If a job of any kind was to be done, he was the first to volunteer for it. One morning he bobbed the hair of half the girl students at the camp, and did it very well. When he spoke seriously of the Filipinos' desire for political independence, we all

listened to him with the greatest respect and sympathy; and vowed to help arouse American public opinion on that subject.[2]

The general tendency to generalize on a few striking cases makes this factor in attitude formation both powerful and dangerous.

Many attitudes arise from a third cause; they may be termed *ready-made attitudes*. These are adopted from the social groups of which the individual is a member, especially from his parents and his playmates. They result from incidental learning more than from direct instruction, and are most often acquired in childhood. If a child hears his parents discuss with alarm and resentment the prospect that a Jewish family may move into a nearby house, he forms an adverse attitude toward Jews. When a child of some nationality is ridiculed and ostracized by a group of youngsters, younger children who observe the occurrence acquire an unfavorable attitude toward his entire nation. Peculiarities and aversions of adult life may often be traced to irrational ready-made attitudes absorbed in childhood, as this illustration shows: "My father, I found out when very young, did not like green. My mother said it was because of its special connection with Ireland. I did not know many Catholics, but heard about a mob of Irishmen which once stoned a Baptist Church during a service. This gave me a reason for being prejudiced myself, and I always feel distrust for them. Whenever I get anything which is green I am very doubtful as to whether I like it or not."

In many instances the subtle experiences that led to the formation of an attitude may be forgotten, while the attitude itself remains. The prejudice may then seem "ingrained" and "natural," and he who holds it may be amazed at the stupidity of persons who do not share his feelings.

Although the most basic attitudes are formed in early life, they can be modified at any time if the necessary influences are brought to bear upon them. Studies that show the considerable

[2] E. C. Carter, *What Makes up My Mind on International Questions.* New York: Association Press, 1926, pp. 49, 50, 72.

effect that a single motion picture or a single course of lessons may have on attitudes indicate the large and desirable changes that can be brought about by more comprehensively planned procedures. Thoughtful educators are paying much attention to the interests and attitudes taught by schools, since they are probably more important than the units of skill or knowledge that the pupils acquire. There is a great need for changes in the attitudes toward war, toward corruption in politics, and toward racial minorities. These may be accomplished to some extent by planned procedures in homes, schools, places of employment, and recreational institutions.

Character Traits

In popular speech a person of good character is regarded as one who has worthy social motives, strength of action in good causes, unselfishness, and a broad view of the world and of his fellow men. The man of character is not swayed by temporary, immediate, or personal considerations, but bases his actions upon future consequences as well as immediate benefits and upon the needs of others as well as his own. This broad definition of character is of some value for provoking thought and discussion, but it is not very useful as a basis for scientific investigation. The broad conception of personality had to be broken down into particular traits before measurements could be made. Similarly, character must be analyzed in terms of more limited *character traits*. Not all components of character have been measured, but experiments have been conducted with respect to honesty, truthfulness, cooperativeness or service, and self-control. Everyone will agree that these traits are important parts of character. They are not the whole of character, but it is better to examine the results of controlled experiments on a few known traits than to speculate about many unknown ones. Most of our knowledge about character traits comes from one research program, the Character Education Inquiry, conducted under the direction of Hartshorne and May from 1925 to 1930.

The Measurement of Honesty. Honesty, or its converse, deceit, can be measured rather easily by giving persons an opportunity to cheat, steal, or lie when they do not expect to be detected, hidden arrangements being used to discover and measure the degree of deceit. No special temptations to deceive are presented, and the conditions are kept as near to real life situations as possible. The Character Education Inquiry tested large numbers of school children with several measures of cheating, both in the classroom and in other situations. One device used for measuring school cheating was the "double testing method." Children were given two arithmetic speed tests of exactly equal difficulty. The first test was scored by the pupil himself by the use of keys distributed for the purpose, and the second test was scored by the experimenter. A legitimate gain would tend to be an improvement from the first test to the second. Therefore, if a pupil scored 30 on the first test and only 20 on the second, there was a strong presumption that he made dishonest use of the key. Another technique was the "duplicating method." A careful copy was made of the child's answers, unknown to him, and he afterward scored the original test. The result of his own scoring was compared to the score obtained from the impartial copy. A rather different method was the "impossible task." Children were instructed to thread mazes, or to mark circles of progressively decreasing size, with their eyes closed. Since these tasks cannot be done successfully without vision, success showed that the child peeked.

Other measures of honesty were devised for use in situations outside of the classroom. At a "party" games were played that permitted the detection of cheating. In an "athletic contest" the youngsters were detected in exaggerated reports of their own performances. Stealing was measured by tests in which the children were given boxes containing coins to use in solving a puzzle. By a concealed method of distribution and identification, the fate of any missing coins could be traced. All these tests were intended for research purposes only, to distinguish the factors associated with honesty among children. Hence

many other measures were made for the purpose of comparing the children's honesty with their intelligence, achievements, home backgrounds, nationalities, religion, parents, church attendance, moral knowledge, and other pertinent traits.

The Measurement of Cooperativeness. Cooperativeness, or the desire to serve others, was another trait measured by the Character Education Inquiry. One test consisted of a competition in which the child could count his score toward an individual prize or toward one for the class, the latter being the cooperative choice. Then the prize money was voted upon, as to whether it would be distributed among individuals, used to buy something for the class or for the school as a whole, or sent to a child in a hospital. In another experiment, children were presented with new pencil boxes and given an opportunity to donate all or part of their contents to poor children who had none. Another test enlisted the youngsters to gather clippings, jokes, and pictures for the amusement of crippled children. Scores were given for the quantity and variety of material and for the care with which it was assembled. A total cooperativeness score for each child was obtained by adding together his performances on the several tests of this trait.

Conditions Affecting Character Traits. Much was learned about character traits in children by comparing the special tests with the other data and measures. From 40 to 75 per cent of all the children tested cheated to some extent on the various tests of deceit. Older children cheated slightly more than younger children. On the school tests of cheating, there was a very marked correlation with intelligence. The "double testing method" found cheating among 21 per cent of the brightest children, 42 per cent of the average children, and 82 per cent of the least intelligent. This distinction did not carry over to cheating outside of school, since intelligence differences were unrelated to the amount of cheating at games. Probably the school is to blame if the dull child cheats, for he finds it his only way for gaining success. There were no con-

sistent sex differences in honesty, and no relationship between physical condition and scores in deceit.

Cheating was most closely related to certain measures of the child's home and family. The socio-economic rating of the home was more associated with cheating than any other factor. In one measure, 16 per cent of the children from the best homes cheated, 52 per cent of the children from average homes, and 100 per cent of children from the poorest homes. Kinship was also important. In the groups tested there were many pairs of brothers or sisters. These resembled each other as much in honesty as in intelligence or eye color. Among the cultural factors that were not correlated with honesty or deceit were religious denomination, motion picture attendance, and Sunday school attendance. This is of interest in view of the faults often ascribed to the motion pictures and the virtues attributed to Sunday schools. Group morale had a marked influence. Some schoolroom groups showed very little cheating; in other comparable rooms every child was dishonest. There was some indication that teachers who had free and cordial relationships with their pupils, and in whose rooms good will and cooperation existed, had a desirable influence on honesty.

Cooperativeness or service was found to be unrelated to age or intelligence. Girls were slightly more cooperative than boys. Children in small-town communities showed better cooperation than did those in larger cities. Socio-economic level had a slight effect upon cooperativeness, but not as much as upon honesty. On the other hand, Sunday school attendance was associated with a superior tendency to do good services for others. There was a strong resemblance in this trait between parents and children, and between brothers and sisters. On the whole, the study of cooperativeness did not lead to as definite conclusions as the study on honesty, probably because cooperativeness is a less unified trait.

All experiments point to the great significance of home influences upon traits of character. Character is learned indirectly

and is molded by a continuous series of experiences. Children become as honest as are the persons with whom they are most closely associated, unless other seriously detrimental factors intervene. The home environment, then, is the chief determiner of good character, and is to blame when it is deficient. Schools and other organizations dealing with children, such as recreational clubs, can also do some effective work in promoting character formation. This is accomplished not by formal lessons or by exhortation and punishment, but by the development of favorable attitudes and by the practice of good traits in many situations.

Chapter XVI

SOCIAL ADJUSTMENTS

The Adjustment Process

Among the many types of adjustment that an individual has to make, his *social adjustments* are usually the most significant. Adjustments must be made to other persons, either as single individuals or as cultural groups, as well as to the material circumstances of the environment. It is therefore appropriate to conclude the survey of human nature with a study of how a person succeeds or fails in his relationships with his fellow men.

An individual's social adjustments are closely related to his personality, for his typical personality traits are shown most clearly when he encounters a serious social difficulty. If life goes on in a calm and undisturbed manner, there is little demand for individuality of behavior since routine habits function smoothly. But if he encounters some considerable social frustration, an individual becomes aroused to more vigorous activity. His fundamental traits of personality are then revealed more strikingly.

The Pattern of Adjustment. Suppose that an employee has been severely reprimanded by his employer for reasons that he considers unjustified. This is a social situation that primarily concerns the employee and employer, but it also involves any fellow workers who may have heard the rebuke, and also the employee's family and friends. The situation also represents the frustration of several important social motives, such as the needs for preeminence, approval, prestige, and security. The adjustments made to such a frustration may vary greatly

in quality and in kind, according to the personality traits of the individual. Good adjustments are made in many instances. The thwarted employee may try to avoid his employer's wrath in the future, may endeavor to bring his real capabilities to attention, and may regain the approbation of his fellows by displaying other desirable social qualities.

Many persons will try to satisfy their thwarted social motives in less desirable ways, however. The employee may seek to restore his self-esteem by becoming a tyrant to his family or by dominating his underlings excessively. He may make too many excuses and point out to all listeners that the criticized act was not his fault, or he may come to believe that his employer "has it in for him." Another method of adjustment is to become sullen and withdrawn, and perhaps to daydream about more successful ventures. The individual may become overanxious and worried about his situation or even develop an apparent illness that explains away his defeat. Most people do all these things when they meet social frustration, but usually only temporarily and in a mild degree. Some persons, however, adopt unfortunate modes of adjustment persistently and strongly, with the result that their entire social life is greatly warped. Why these people ruin their social adjustment by trying too frantically to achieve it is one of the most significant processes upon which psychology can throw some light.

The analysis of a process of social adjustment shows that it is a sequence having four distinguishable components. Some strong social *motive* meets with a *frustration*, or a baffling difficulty that cannot be overcome readily. Impelled by the still unsatisfied motive, the individual makes various attempts to fulfill it, which result in trial and error or *varied responses*. Finally, he hits upon some *solution*, either complete or partial, that ends the adjustive sequence because it satisfies in some degree the motive that demanded the adjustment. In brief, then, the adjustive process may be stated in terms of

(1) motive, (2) frustration, (3) varied responses, and (4) solution.

It will be seen at once that this is exactly the analysis that was employed to describe the process of problem-solving (Chapter XIII). Indeed, social adjustment is one form of problem-solving, and it is appropriate to represent it in the same terms. It is a sufficiently distinctive sequence, however, to justify a separate and extended description.

The motives that call for adjustive behavior have already been enumerated in Chapter VII. Adjustments of a sort are evoked by all kinds of motives, even of the most trivial varieties. An individual may adjust to the nondelivery of the evening newspaper or to the fact that he has smoked his last cigarette. But the most important adjustments are made to the strong social motives, those designated as the needs for preeminence, mastery, conformity, approval, prestige, recognition, security, affection, and sex. These motives originate from strong emotional reactions, as was described in Chapter VII, and develop through social experiences. Consequently they are aroused in the main by the presence of other persons, and retain a large emotional component that is expressed strongly when the motive is thwarted.

Forms of Frustration. A motive may be thwarted by an entirely inanimate obstacle, or by some direct or indirect result of the activities of other persons. The first of these forms of thwarting may be termed *material frustration* and the second *social frustration.* In general, persons adjust constructively to material obstacles, either solving the difficulty to the best of their abilities or giving up the attempt with no undue show of emotion. A scientist working on a difficult laboratory problem is one of the most frustrated of men, but he seldom rages at his apparatus, nor does his material frustration result in unfortunate substitute adjustments. Abstract and mechanical problems therefore evoke the best reasoning of which the individual is capable, and usually culminate in effective adjustments.

Social frustration, on the other hand, is quite likely to evoke

emotional behavior, and therefore to result in less successful adjustment. The instances in which a material obstruction seems to produce emotional behavior, in fact, are almost always those in which the frustration is really social. If a man is driving alone when his automobile stalls and refuses to proceed, he will most often seek to repair it, summon help, or find another mode of transportation, all in a relatively calm and constructive way. But let the car contain his family or other passengers and the situation will be quite different. He then is likely to berate the engine, make far-fetched excuses for its nonperformance, and become quite stirred up, especially if the other persons make critical comments or offer well-meant advice as to what he should do. Although the man may express his irritation toward the inanimate automobile in such a case, he is actually adjusting to the social group. It does not really matter that the automobile thwarts him. What is of grave concern is that it should make him seem a fool before his fellows.

Among social frustrations two principal subtypes may be distinguished, although these blend into each other in some instances. Some social frustrations are due to the *personal inability of the individual to achieve the standard set by the expectation of his social group.* This is sometimes referred to as a thwarting because of "inferiority," but the mere existence of a low degree of ability does not lead to maladjusted behavior. A boy who is dull in school may not suffer from any sense of inadequacy if scholarly accomplishment is not esteemed by his parents or playmates. But a boy who cannot run, jump, climb, or fight as well as his associates suffers a serious adjustive handicap because these traits are highly regarded by the social group from which he derives his adjustive values. Similarly, an average adult is not thwarted because he is not a great artist, musician, or inventor, since these accomplishments are not expected of him. Any characteristic that brings scorn, suspicion, or criticism from his equals, however, is likely to precipitate an adjustive difficulty.

Another, and more subtle, social frustration arises when *a strong immediate motive is thwarted by the individual's social habits and values.* For example, a young girl had learned throughout her life to love and admire her parents, as most children do. Furthermore, social custom decrees this to be the "right" attitude for children to have. This sentiment is therefore a firmly established social habit or value, strongly supported by all social motives. Now, suppose that the girl learns that her parents are unworthy, that both have been carrying on clandestine love affairs, and that they bitterly threaten each other with divorce. Her immediate reaction is to despise and shun her parents, but this is prevented by the long-established habits. She is therefore frustrated, and must effect some sort of a compromise adjustment. Since this type of frustration may be carried out entirely in thinking, it is sometimes called a "conflict" of thoughts or motives. But it is nevertheless a social frustration, although society is represented implicitly by the individual's attitudes and values rather than by the overt pressure of other persons.

How much frustration will be represented by a given situation depends greatly on the strength of the motives of the individual concerned. To take candy away from a child may be no frustration—if the child does not like candy. An end result that is highly motivated will be frustrated by a very slight obstacle. Suppose, for example, that an individual has been badly "spoiled" in childhood by parents who lavished praise and sympathy on him and satisfied his every whim. Such a person acquires an abnormally strong motivation to receive social approval and sympathy. Hence he is easily thwarted by circumstances that would not affect another individual whose background is different. Some students believe that their teachers are prejudiced against them merely because the teachers treat them objectively without the undue consideration that they have come to expect from their parents. Similarly, if an individual has always had his difficulties smoothed by others, and if he is always praised, he may develop an exag-

gerated motive for preeminence and mastery. Any minor criticism or obstruction then calls forth excessively intense adjustive behavior. The reason that the same situation is not equally frustrating to all people, then, depends largely upon the differences in their motives, which in turn depend on the differences in their social training.

Direct and Substitute Adjustments. Many frustrations, even strong social ones, are resolved by direct and worthy adjustments. These are usually unspectacular and go unnoticed in the course of everyday life. We admire a man who overcomes handicaps and who encounters criticism without becoming spiteful, but there is little that can be said about him psychologically. Few studies have been made of persons who adjust uncommonly well. Psychology can aid good adjustments to some extent, however, by discovering the nature and causes of unfortunate ones.

Most of the unsatisfactory and socially undesirable adjustments are indirect or substitute adjustments. They are partial or compromise solutions of the drive that is thwarted, and hence satisfy it inadequately. An individual who is frustrated in his attempt to secure esteem and prestige in a social group may adjust by "showing off." He may talk too loudly, affect eccentricities of speech and manner, or hold tenaciously to peculiar opinions. These traits serve to bring him notice, and therefore partially and temporarily satisfy his need for social approval. But they hinder his full and permanent adjustment because they make people dislike him more than ever. This illustration defines the distinction between good and bad social adjustments. An inadequate adjustment is a partial, immediate satisfaction and is adopted by the individual because it is the best that he can attain at the time in response to an insistent urge. An adequate adjustment not only is satisfying for the present, but it also facilitates the making of other good adjustments in the future.

Evidence both from experiments and from the study of cases of individual behavior shows that inadequate adjustments are

most often made when the frustration arouses a strong emotional response. This is understandable, because emotion is a state of disorganized behavior in which clear thinking is inhibited. The emotional character of maladjustment helps to explain its inconsistencies. The socially frustrated person tries too hard to overcome the thwarting, with too much emotion and not enough judgment, and thereby only adds to his difficulties instead of resolving them.

The substitute ways that people use to satisfy thwarted motives are termed *adjustment mechanisms*. Mechanisms are habits of response, hit upon by trial and error, and retained because of their partially satisfying qualities. A number of the more common adjustive mechanisms have been given special names, such as compensation, rationalization, seclusiveness, and fantasy. These names are useful, for they help us to describe and to remember the varieties of behavior that they designate. They do not represent invariable "types of cases," however. To understand social adjustments, it is best to consider each individual not as a type, but as a human being who is in trouble.

Some Common Substitute Adjustments

Compensation. One of the most common forms of substitute adjustment is the development of overaggressive behavior in response to social frustration. *Compensation* is an overemphasis of a characteristic that serves to relieve or conceal the inability of the individual to achieve a standard set by social expectation. Bullying, for example, is frequently a compensatory form of behavior. The school boy who bullies younger children often has failed to secure a satisfaction of mastery motives among children of his age because he is puny, clumsy, or lacking in other qualities that boys esteem. Hence he bullies smaller youngsters to assert his strength and adequacy, and to make people notice him. Among adults the same behavior exists, for the petty tyrant is usually one who is basically uncertain of his own capability.

Compensatory behavior underlies many of the social adjustment difficulties of college students. L. C. Pressey (1929) gives a case study that illustrates this.

A young man came to the University from a farm. His only social contacts had been obtained in country schools, and his entire manner, language, and dress revealed his lack of cultural background. After a short time he began to have trouble with his fellow students and instructors. He appeared to be extremely conceited, offered sarcastic criticisms to his professors, and tried to domineer over the other students. In a campus restaurant he was often observed going from table to table, talking loudly and familiarly with other students who, however, avoided him as a pest. When summoned for an interview with the psychologist, he appeared in clothes cut in an extreme fashion, and seemed excessively aggressive and self-confident. It was discovered that at other times he showed despondence and seclusiveness that alternated with his overaggressiveness. Under the guidance of the psychologist he was induced to admit that his behavior was a frantic attempt to cover up his social handicaps and to represent himself as a popular and self-sufficient person. He was then helped to understand why he had acted in this way. With his new insight into the sources and consequences of his conduct, he was easily persuaded to give up his compensatory behavior. Further guidance was given to correct his principal faults of speech and manner, and he succeeded in readjusting on a more calm and modest basis.

Many compensations are of a less obvious sort. Gossip, for example, is a compensatory mechanism. A person who lives a relatively drab and uninteresting existence is usually very ready to tell and retell any bit of scandal that concerns neighbors or acquaintances. Gossip of this kind provides a vicarious or substitute satisfaction, and the gossiper takes great joy in the sordid facts that are rumored, even though the tale is told under the guise of criticism or disapproval. A still more indirect type of compensation is found when parents secure adjustive satisfaction through their children's achievements. A parent who has always wanted to enter a certain profession may force his child to follow it, regardless of the latter's true interests or ability. When the child is sufficiently capable no harm may be done; but in other instances the youngster may acquire a pessimistic attitude either as a result of his failure

in the chosen field, or because he desires to enter some other occupation of which the parent disapproves.

Although most compensations are socially undesirable, not all of them are maladjustments. If an individual has an irremediable physical or social handicap, a compensatory interest in some hobby or accomplishment may represent the best adjustment that he can make. A crippled boy who cannot play active games may develop a compensatory interest in music, in scholastic achievement, or in collecting stamps that serves to make him feel important. A childless woman's compensatory activity in a child welfare agency may bring very socially desirable results. Campaigners and reformers are often impelled by personal motives rather than by abstract ideals, but they often accomplish some good in spite of the sources of their interests. Compensation must be regarded as a trait that all persons use to some extent in their daily activities, and not solely as a symptom of social maladjustment.

Rationalization. A person may adjust by talking or thinking as well as by overt activity. *Rationalization* is an adjustment mechanism in which the individual gives socially acceptable reasons to justify his conduct, either verbally to other persons or by inner speech to himself. The need for rationalization arises whenever an immediate motive runs contrary to an individual's conceptions of social values. He wants to engage in some greedy, spiteful, or unworthy act that will bring him immediate satisfaction. But he also wants his act to appear socially desirable, or at least excusable. So he does as he pleases, and justifies his conduct by defending it with rationalizations. The concepts of "good" reasons and "real" reasons help to explain rationalization. The real reasons are the motives that underlie the act which the man does not want to admit even to himself, much less to the public. The good reasons are those that he devises to deceive himself and others. A person who rationalizes is not lying in the ordinary sense. He deceives himself first, and is utterly convinced of the soundness of the reasons that he advances.

Rationalization is illustrated by many events in everyday life. A business man, defending himself against feeling ashamed of a shady deal, says that "business is business," and points out that all his competitors are following the same practice. A mother reconciles herself to her child's bad habits by believing that they were inherited from the father's side of the family or else acquired from the neighbors' children. If a college student earns a good grade he says, "*I* got an A," but if he fails he says, "*The professor* flunked me." Thereby he takes credit for his successes, but blames his failures on someone else. Attitudes are usually defended by rationalizations. A man who dislikes Negroes, for example, will be able to cite many psychological, economic, and social arguments against the race. His real attitude was probably formed irrationally by some striking incident, or was adopted from the attitudes of his parents or associates. But he is intensely convinced of the rightness of his opinion, and so discovers many good and apparently logical reasons for holding it.

In some instances, rationalization functions as a major adjustive mechanism in an individual's life, and plays a part analogous to compensation. A mild and genial man occupied a position in a department store hearing the complaints of customers and employees. Because of his success in this work he was eventually elevated to the position of general manager. At this time a business depression became very severe, and his superiors exerted great pressure on him to lower the wages and increase the hours and duties of the employees under him. He was much irritated with his superior officers, but not being able either to resist them or to retaliate against them, he carried out their wishes. Gradually he became almost tyrannical in his treatment of the employees. Concurrently, he developed a rationalization for his conduct by a growing belief that his subordinates were refusing to cooperate with him, were blocking his program, and were trying to bring about his downfall. These rationalizations were compromise adjustments to several unpleasant situations, namely (a) his inability to cope with

his superiors, (b) his enforced harshness toward the employees whom he had previously treated kindly, and (c) his fear of being a failure as a manager.

Rationalization is not reasoning, for it has only the deceptive form of reasoning without its intent or purpose. Reasoning is a process of seeking a true answer to a problem, whereas rationalization justifies an answer that has already been determined by desire. Because of this, rationalization is often called *wishful thinking.* If reasoning is foresight, rationalization is hindsight. Unfortunately there is more rationalizing than reasoning in the world, and much that passes for thinking is really justification.

Withdrawing. Some people adjust to their social difficulties by *withdrawing* from the situations that provoke frustration. This is a simple and direct adjustive mechanism, analogous to that of the burnt child who fears the fire. It is characteristic of shy and seclusive individuals. Withdrawing furnishes some adjustive satisfaction, because a person who will not try to make social adjustments cannot experience the frustrations of failing or of being rebuffed. Shy people do not make nuisances of themselves, hence their maladjustments are often not discovered. Among school children, in particular, seclusive youngsters are frequently deemed to be models of deportment, but they are as much in need of real satisfactions as are the overaggressive children. An individual's use of withdrawing as an habitual adjustment may arise from a number of causes. Some persons hit upon it in the course of trial and error, and retain it because it is satisfying. Others may adopt shy and seclusive behavior because it happens to be the preferred adjustment of the individuals on whom their lives are patterned. In many instances an intensified and fearful withdrawing response follows the violent frustration of some more active form of adjustment, as when parents seek to control a child by harsh and repressive discipline.

A quite different kind of withdrawing response is found in *negativism*, which is an active, and sometimes violent, refusal

to cooperate socially, often accompanied by an emotional reaction of the rage type. Among very young children two to three years of age, negativism is so common that it is almost normal. A child that young cannot understand many of the restrictions imposed upon him, yet has many interests and desires. When adults interfere with his activities he easily falls into the habit of refusing to comply with any demand, no matter how reasonable. In the usual course of development, negativism wanes as the child acquires a better understanding of social requirements and learns other ways of expressing his wants. Negativism may be carried into later childhood, however, if it has been successful in getting adults to yield. The way to perpetuate it is to give the child what he wishes whenever he has a tantrum. Negativism may also be continued if a child is unduly frustrated and can find no other adjustive outlets.

Among adults, intense outbursts of negativism are very uncommon, but milder equivalents are often encountered. Holding grudges and refusing to cooperate in any activity initiated by a person against whom one is prejudiced are forms of negativism. These responses are most often directed against someone in authority whom the individual is afraid to attack directly. Negativism is not a satisfying adjustment, but it relieves the feelings of the person who uses it by asserting his independence and showing his refusal to be led against his desires.

Daydreaming. Most people find adjustive satisfaction in *daydreaming* or *fantasy*, and this form of gratification is especially common among those who are withdrawn and seclusive. Daydreaming is adjustive, for in his fantasies the individual pictures the attainment of motives that he cannot satisfy in real life. The daydreams of quite normal people often deal with very improbable occurrences, but represent the fulfillment of strong motives. One common type is the "conquering hero" daydream, in which a person imagines himself performing feats of great physical strength, making brilliant remarks, at-

taining high rank in his occupation, accumulating great wealth, or securing the favorable attention of a desired partner of the opposite sex. The converse is the "martyr" daydream in which the individual imagines himself abused, injured, or killed. Although melancholy, this dream is really satisfying, because it is an expression of self-pity and a compensation for a lack of sympathy or approval from other persons.

Daydreaming is not an abnormality in itself; it is extremely common in the lives of even quite well-adjusted people. In one study, a group of 195 college students reported the types of daydreams in which they engaged. Nearly all the group reported that, at some time in their lives, they had daydreamed of occupational success, of having money and possessions, and of securing the attention of the opposite sex. From 66 to 81 per cent had daydreamed on each of these three topics during the month preceding the investigation. These results show that daydreaming is an ordinary adjustment, similar to excuse-making and the milder compensations, because so many people depend upon it to lighten their frustrations.

The chief condemnation of daydreaming arises from the fact that it is a waste of time. Many students upon encountering a difficulty in their studies drift off into pleasant revery, only to discover a half-hour later that time has passed and no work has been done. Another undesirable result of daydreaming is that it enables the dreamer to satisfy his motives unsocially and without effort. In consequence, he is less likely to try hard to achieve real and actively gained social adjustments. On the other hand, some positive values can be found in fantasy. No hard and fast line can be drawn between daydreaming and planning, except that the latter is concerned with more probable future accomplishments. Also, the creative products of artists and poets are often the results of fantasies, and would be impossible in a world devoid of daydreaming.

Adjustment by Becoming Ill. A rather surprising way in which people may resolve their adjustive difficulties is by developing the symptoms of an illness. An uninformed per-

son may find it hard to believe that sickness can arise through psychological processes, but an illustration will remove much of the doubt. Some children will vomit whenever they are frustrated. This trait originates from a process of habit formation. On some occasion the child may have been very much aroused emotionally because of thwarting. This emotional state interfered with his digestion, as it always does, and perhaps some other factors contributed, such as irregular eating or excessive crying. As a result of these purely physiological factors, psychologically aroused, the child became nauseated. At once the attitudes of the persons about him changed. Instead of being scolded, he now received sympathy, and was put to bed and pampered. No far-fetched hypotheses are necessary to explain how the child can get sick more quickly and easily when he is thwarted again. The vomiting reflex is a muscular reaction, and can be conditioned quite readily to substitute stimuli. When frustrated, the child feels miserable with self-pity and promptly becomes sick as an adjustive mechanism.

Many adults also resort to illness as an adjustment. Physicians recognize that an appreciable proportion of their patients have no real organic disorder, but develop symptoms for adjustive reasons. Some persons believe that they suffer from "heart disease," for example, because their hearts beat rapidly and strongly at times. But this is only another physiological effect of emotion, and is easily aroused by a social difficulty. Even pains may be experienced because of adjustive needs. It is more than a figure of speech that a distasteful task "makes you sick" or "gives you a pain." Headaches, in particular, can arise in response to an emotionally toned frustration. A classic example is the "nine o'clock headache" which is very intense at that hour, but which soon subsides when it is too late to go to school or to work. A closely related adjustive device is the exaggeration of a "real" but minor illness. Some persons cherish their ailments fondly and seem indeed to "enjoy poor health."

Having an illness has adjustive value for an individual because it facilitates withdrawal from difficulties, arouses sympathy, helps to control others, and assists in rationalizing away failures by blaming them on poor health. A person who has an adjustive ailment stumbles upon it in the course of blind trial and error learning, and without any deliberate intent. These ailments are not pretended, but are very real to the one who is experiencing them. He deeply believes in the reality of his symptoms, and does not realize their nature, origin, or adjustive utility. A malingerer is one who claims a disability that he knows to be false, but a person suffering from an adjustive ailment is sincere, in the ordinary sense. In this respect an adjustive ailment is like a rationalization, for the rationalizer is utterly convinced of the truth of his wishful contentions.

The habit of adjusting by means of illness is best prevented in childhood. A real illness should not be made too pleasant for a child, and emphasis should be placed on the privileges dependent upon good health. It is fundamental, of course, to give every youngster his proper share of satisfactions of motives such as mastery, approval, and security, so that he does not have to become ill to gain attention and sympathy. Adults who have already developed adjustive ailments may be cured in many instances, first, by giving them insight into the causes of their symptoms, and second, by aiding them to discover more constructive adjustments to the original frustration.

Failures of Adjustment

Persistent Nonadjustive Reactions. In some instances an individual may experience a serious social frustration and fail entirely to find any way to adjust to it. Any severe thwarting elicits an emotional response which, in the normal course of events, is reduced either by a good adjustment or by one of the substitute adjustments that have been described. When no adjustment, either good or poor, is made to a situation the individual's emotional state remains unreduced, and he

makes a *persistent nonadjustive emotional reaction* to his baffling difficulties. The presence of persistent emotion has a very unfortunate effect on his physiological processes and on his adjustive behavior. In everyday life persistent nonadjustive reactions take the forms of *worry* and *nervousness*.

Nonadjustive emotional reactions have been induced experimentally in lower animals. From the results of these experiments some of the causes and effects of this unfortunate condition can be inferred. The earliest observations of this sort were made in experiments dealing with the conditioned reaction,[1] and indicate that persistent nonadjustive reactions may be caused by an *excessive strain on the discriminative functions* of the animal. A conditioned discrimination can be taught an animal by training him to respond to one stimulus but not to respond to another rather similar stimulus. In the first experiment reported, from a Russian laboratory, a dog was being taught to discriminate between circles and ellipses presented visually. He successfully differentiated a circle from an ellipse whose axes were as seven to eight, but when a finer discrimination was demanded by presenting a circle and an ellipse whose axes were as eight to nine, his behavior changed suddenly and spectacularly. First, the dog became very excited emotionally, and barked, snapped, and tore at the apparatus. Second, he was no longer able to make discriminations of the easier sort that had formerly caused no difficulty. This condition was termed *experimentally induced neurosis*, and persisted for at least several months.

Further experiments in American laboratories have unearthed more facts about discriminative "breakdowns." Liddell brought about experimental neurosis in one-fourth of a number of sheep that were tightly strapped in the usual laboratory apparatus. He discovered, however, that sheep who were free to move about while being conditioned could not be broken down. It seems, therefore, that *restriction of freedom* is a necessary cause of the disorder, as well as discriminative

[1] See pp. 113-121.

strain. Liddell also reported that the social behavior of the animals was permanently affected by an experimental breakdown. The "neurotic" sheep would not feed with the others or follow them, and seemed excessively seclusive and stubborn. One sheep continued to show maladjustment until the onset of senility at the age of thirteen years.

Experimentally induced neurosis has been evoked by other situations than the conditioned discrimination experiment. Karn (1938) reported the breakdown of a cat in the double alternation problem.[2] In this difficult maze task, the animal must make four successive turns at the same point in the order right, right, left, left. One cat had attained 90 per cent accuracy after 230 training trials. When more trials were given to see if the accuracy could be increased further, a "neurosis" occurred. The cat either hesitated and sulked, or else dashed from one alley to another. It scratched and clawed at the apparatus and at the experimenter, and strongly resisted being put into the maze. Furthermore, its accuracy of performance decreased progressively. It reverted to an incorrect order of choices that it had used in the earlier trials but which it had discarded with improved mastery. Another experimenter has caused violent and apparently "neurotic" behavior in rats.

In summary, violently nonadjustive behavior has been called forth when animals have been deprived of freedom, and made to attempt a discrimination that taxes their abilities excessively. As a result they become overemotional, aggressive, and uncooperative. Also they lose much of their previously acquired ability to adjust and discriminate, and revert to inferior habits of response. These disabilities transfer to the animals' ordinary lives outside of the laboratory, and persist for a long time.

Nervousness and Worry. The most common forms of persistent nonadjustive emotional reactions found in normal human beings are nervousness and worry. *Nervousness* ordinarily designates an irritable, unstable, "jumpy" condition of

[2] See p. 348, and Fig. 101.

behavior. The "nervous" person cannot endure frustration, and becomes emotional upon slight provocation. Of course there are many degrees of nervousness, and almost everyone is at least a little nervous in some situations. A student who sits in the outer office awaiting his turn to receive a reprimand from the dean may display this type of reaction. He fidgets, cannot sit still, starts violently if there is a sudden noise, and is preoccupied with distressing thoughts. When the interview is over these symptoms may soon disappear. Nervousness of this sort is the result of a fear reaction, and if the fear is temporary so is the nervousness.

Chronic or habitual nervousness is best explained as a persistent nonadjustive reaction similar to that found in the animal experiments just cited. The individual faces an adjustive problem that requires discriminations or choices that he cannot make. He fails to discriminate not because of a lack of intellectual ability, but because the situation conflicts with his social habits and motives. The "nervous" housewife, for example, may be unable to resolve the conflict between her acquired sense of duty and her dislike for domestic work, or between her need for love and attention and the neglectful attitude of her husband. In other instances there may be no immediately present frustration, but the individual remains "nervous" because of the after-effects of a particularly distressing past experience, just as an animal who has been "broken down" continues to show peculiar behavior. Difficulties that occur in childhood, as when a youngster is nagged and harassed by erratic and unstable parents, may leave a mark on his conduct throughout his life.

Persistent nonadjustive reactions have certain pronounced effects on the physiological processes of individuals. All strong emotional reactions interfere with the normal digestive movements of the stomach and inhibit the secretion of digestive juices, as was described in Chapter VI. When emotion is almost continual, as in cases of chronic nervousness, the effect upon digestion may become serious. This is often called "nervous

indigestion," and may be accompanied by visceral pains and headaches that are secondary results of the digestive disorder. A normal emotional reaction is an emergency state, not intended to be maintained for a long time. If an individual remains stirred up emotionally for a considerable period, therefore, he lacks nutritional energy to maintain his bodily processes at the normal level. Because of excessive energy expenditure accompanied by poor digestion, the "nervous" person may lose weight alarmingly. Thus he "worries himself thin" because he is unable to maintain his nutrition properly. All these organic disabilities arise from purely psychological causes, namely, from persistent nonadjustment to baffling difficulties. They result not from any mysterious "influence of the mind on the body," however, but from the physiological effects of continued emotion. Many so-called "nervous breakdowns" are severe, persistent, nonadjustive, emotional reactions.

A widespread popular misconception holds that nervousness is due to "weak nerves." This notion is entirely wrong and receives no support from either medical or psychological science. The error arises in part from misinformation, but even more from rationalization. Many people like to believe that their nervousness arises from "weak nerves" because this conviction helps them to rationalize about their failures. It is more consoling to think that one's troubles are due to an uncontrollable organic disorder than to admit that one has failed to make an adequate social adjustment. It is true that a number of organic conditions may affect the individual's adjustive behavior, but not in the way that is popularly supposed. Some disorders of the endocrine glands, some chronic infections, and some diseases with annoying or painful symptoms may cause restless, irritable, and nonadjustive behavior. Most ordinary nervousness does not arise from these causes, however, but comes about psychologically.

Worry is the verbal counterpart of nervousness. It is persistent nonadjustive thinking. The worrier goes over his troubles again and again, reviewing the same distressing cir-

cumstances and thinking of the same inadequate outcomes, but is unable to solve his troubles. Like nervousness, worry occurs in all degrees of intensity; smaller worries are very common. Of a group of 195 college students questioned in one study, 52 per cent reported that they had worried at some time during a thirty-day period. When a worry is concerned with a minor and specific problem it is likely to disappear when the difficulty is solved or when some other interest or satisfaction diverts the individual's attention from it. Chronic anxiety often arises when the worrier is stimulated by a persistent, important, and relatively insoluble personal problem, such as inadequacy of occupation, fear for his health, incompatibility with his family, or inability to get along with a social group. In still other persons worry may become a fixed nonadjustive habit because of long-continued anxiety over some earlier frustration. Such a person will discover or invent one cause for worry after another, even when no objective difficulty exists. Chronic worry and chronic nervousness are hard to cure, since they have become firmly established habits of personality. Common experience shows that persistent worry cannot be relieved merely by reassuring the worrier or by proving that his fears are groundless.

Serious Mental Disorders. The greatest failures of adjustment are found in the lives of persons who become mentally disordered and have to be cared for in mental hospitals because they cannot get along in any kind of ordinary social environment. "Insanities," or more properly the *psychoses*, are much more common than most people realize. From 8 to 10 out of every thousand adult persons are patients in a mental hospital at some time during the year. Out of every thousand persons born, about 50 will be in a mental hospital at some time in their lives. The cost of maintaining the half-million mental patients in hospitals in the United States is about one hundred million dollars annually. Serious mental disorders therefore constitute a grave social and economic problem.

Mentally deranged persons are not a class apart from other

people. They are human beings. An unsophisticated visitor to a mental hospital is usually surprised to see how normal most of the patients seem. Very few are violent or intractable; most of them are just pitiful individuals who are bewildered by the world and cannot adjust to it.

Mental disorders are divided into two principal groups. In one classification are the *organic psychoses* that are due to brain deterioration in old age, syphilis of the nervous system, chronic alcoholism, and a number of other identifiable physiological causes. These patients constitute about one-half of the population of mental hospitals. Although the causes of the organic disorders are primarily physiological, psychological factors are also present in some cases. A senile person who distrusts everyone and believes that he is being poisoned shows only an exaggeration of a tendency to be unduly suspicious that he has established by a lifetime of habit formation. A chronic alcoholic often took to drink to escape a baffling social frustration. Except for the conditions due to old age, most of the organic psychoses are preventable, and some of them can be wholly or partly cured by appropriate treatment.

The other half of the patients in mental hospitals suffer from the so-called *functional psychoses*, in which psychological causes have a much greater share. Physiological factors are not entirely absent from the functional disorders, however. Although the evidence is not conclusive, it may be suspected that inadequate nutrition of the brain cells, glandular disorders, and certain infections may predispose an individual to a psychosis. Heredity is often mentioned as a possible cause of mental disorders, but the evidence is not entirely conclusive. Certainly, no one has scientific grounds for concern about his own mental health merely because there is a case of psychosis in his family. It is probable that the causes that precipitate a functional psychosis are mainly psychological. These psychoses can be understood best as extreme types of persistent nonadjustive reactions to baffling personal and social difficulties. Most cases

of functional psychosis fall into two classifications, namely, schizophrenia, and manic-depressive psychosis.

Schizophrenia, also called *dementia praecox*, is characterized principally by great apathy or indifference to the environment, and some degree of emotional disintegration. The person who suffers from this psychosis is typically withdrawn and pays little attention to other people. Sometimes this apathy takes the form of silent seclusiveness and a loss of all interests, while in other instances peculiar behavior develops that has little relationship to external situations. Delusions, or fixed false beliefs, are common in schizophrenia and also occur in several other psychoses. A deluded patient may believe, for example, that he is persecuted and that his family has stolen a large sum of money from him. Delusions seem to serve the same purpose for the mentally disordered that rationalizations do for normal people. The delusions bolster up their sense of self-importance, and help them to explain away their defeats and failures. It is easier for a psychotic person to believe that he is persecuted than for him to admit his mental breakdown. Schizophrenia is a psychosis typical of early life. Although some cases occur at any age, the peak is in the decade from twenty to thirty years of age.

Manic-depressive psychosis is shown either by excitement and superficial happiness in the "manic" state, or by slowness and melancholy in the "depressed" condition. These phases constitute one disorder because both are abnormal variations in emotional tone, and because they are often found in the same person at different times. An individual may have an attack of the manic type, and a year or two later have one of the depressed variety, or vice versa. Manic-depressive psychosis is characteristic of middle life, being most common among persons forty to fifty years of age. Most patients recover from a single attack, but many people have recurrences.

It is important for persons to have a constructive attitude toward the nature, causes, and extent of the psychoses. Mental disorders are often concealed because of an unfounded super-

stition that they are disgraceful or that they represent a "taint" in the family. Psychoses are no more a disgrace than any other form of illness. If a member of the family becomes very withdrawn, acts in a peculiar way, is despondent, threatens suicide, or shows marked changes in personality, a psychiatrist should be consulted at once. A *psychiatrist* is a medical doctor who specializes in the diagnosis and care of mental disorders; his services can be procured through the family physician. One of the worst effects of the popular dread of mental disorder is the refusal to recognize a case of it until the symptoms are far advanced. All disorders can be helped more effectively if they are placed under competent care in the early stages of development. The outlook for the cure of the psychoses is not bright, but it is not nearly so bad as many people think. Ordinary mental hospitals discharge as many as half of their patients, cured or improved. Some excellent private hospitals where more intensive treatment is used, achieve much better results. Further progress will come through scientific research, and through better public cooperation when the unfounded dread and fear of mental disorders have been lessened.

The Hygiene of Personality

One of the most beneficial uses of psychology is its application to the cure and prevention of the minor abnormalities of behavior found in normal people. This field of psychology is usually termed "mental hygiene," and may be divided into two parts. First, certain psychological procedures are used to assist people who already show social maladjustments. Second, some positive principles may be stated that will assist in preventing socially inadequate behavior.

The Guidance of Readjustment. Mental hygiene service is rendered to individuals who need it by psychiatrists, some other physicians, psychologists, social workers, school administrators, and teachers. These different professions represent various degrees of training and competence for dealing with adjustive problems, and attack them with varying degrees of

success. As a convenient term, any trained person who practices mental hygiene professionally may be called a *clinician.* In recent years, mental hygiene clinics have been organized in the larger cities in which the services of psychiatrists, psychologists, and social workers are combined.

The first procedure employed by a clinician is to gather all the pertinent information about the person who is to be assisted. The most significant facts, of course, come from the individual himself. Long conversations with the clinician draw from the person his conception of his difficulties, his attitudes, his traits of personality, and the history of the experiences that have led to the formation of his inadequate substitute adjustments. The individual is encouraged to talk freely at first and to tell his own story without interruption. Afterward questions may be asked that are suggested by his story or that concern common areas of maladjustment that he has omitted from his own report. One of the clinician's important tasks is to establish a confidential contact with the person that will induce him to disclose past experiences of which he is afraid or ashamed. Even when an individual has come for help voluntarily he will often try to hide many valuable facts. These usually come out after several interviews, when he has gained confidence in the clinician's integrity and fairness and has had practice in expressing himself. What the patient says is often not accepted as literal fact by the clinician. The patient will reveal prejudices, aversions, and topics on which he is emotionally upset, and these are important data about his personality.

In guidance clinics that have highly organized staffs, other information is usually gathered about the patient. Mental tests are used to determine his intellectual ability, and other measures of special abilities or achievements may be used occasionally. A thorough physical examination discloses any organic factors that may have contributed to the maladjustment. The conditions of the patient's home and environment may be investigated directly by specially trained social workers.

In some cases, reports are secured from parents, teachers, and other associates, or these persons may be interviewed.

The curative work of mental hygiene is carried out chiefly by talking with the individual. In a broad sense, it is an educative process designed to stimulate and assist him to work out a better adjustment to his difficulties. First, the interviews by which the clinician draws out the individual's story have considerable remedial value. In these talks, the patient sees his problems as a whole and gets a clearer view of his own abilities, motives, frustrations, and inadequate adjustments. His subterfuges are laid bare before him and he understands, usually for the first time, why he acts as he does. Since he has to tell about his emotional experiences and personal handicaps in an objective way, he gradually becomes less emotional and more objective toward them himself. This is a process of "extinction," or the unlearning of a conditioned reaction by repeating it without reinforcement. Later in the treatment process, the individual is encouraged to make new and better trials in the trial and error process of adjustment. It must be emphasized that the clinician does not give advice authoritatively or tell the patient how to readjust. Good advice could be given at the outset, but it would probably not be put into practice. In order for the cure to be effective, the individual himself must discover the nature of his adjustive difficulties, and must make his own decisions on the improved types of responses that he should make to his frustrations.

Along with the individual treatment, attempts are sometimes made to modify environmental conditions that cause avoidable frustrations. Sometimes the social environment is at fault rather than the individual. In one instance a college freshman became seclusive, nervous, and deficient in his studies. Investigation showed that he had marked artistic, literary, and musical interests, but that he was by no means a sissy. By chance he had been assigned to a dormitory where his closest neighbors were "roughneck" students whose chief sport had come to be the ridiculing of this boy's serious in-

terests. A change in his place of residence was all that was needed to effect a satisfactory readjustment. The structure of society in the broader sense underlies many maladjustments. Persons who lack security and who have no opportunity to obtain a sense of mastery or self-expression in their work cannot be entirely well adjusted. The most useful temporary expedient is to modify the individual to fit his environment, but in time certain features of social institutions will have to be modified to make them more suitable for the people they serve.

Positive Psychological Hygiene. The psychological study of social adjustments and maladjustments has resulted in some tentative principles which an individual may use to attain a more stable and effective life.

To improve one's own adjustive behavior, the first need is for an *objective attitude* toward it. An objective attitude is based on careful and unbiased observation, and is not unduly influenced by rationalization or prejudice. No one achieves this standard perfectly—"to see ourselves as others see us"—but the degree of objectivity that a person can attain is positively correlated with the merit of his adjustments. The objective individual has *insight* into his own conduct, and has acquired his typical adjustments not by blind trial and error, but with an understanding of the ends that he is seeking and of the means that he is employing to gain them. Objectivity must be accompanied by an *active attitude*. Merely to examine one's own character may be morbid, but to evaluate it and then to take planned action to remedy defects and to achieve the satisfaction of legitimate motives is constructive. The well-adjusted person also pays primary *attention to the present.* Most maladjusted persons are excessively concerned with either the past or the future. The worrier, for example, fears what tomorrow will bring and regrets what happened yesterday. Of course, one must profit from the past and plan for the future, but these tasks are achieved most effectively by seeing what can be done in the present situation.

It is important for every individual to *maintain a confi-*

dential relationship with some other person, and to talk with him freely about adjustive difficulties. A trouble or worry seems much less severe if it is discussed with a friend whose attitude is impartial. Most maladjusted people suffer from an inhibition against confiding their real difficulties, which they conceive to be shameful, and against seeking advice. Aside from the value of the counsel that may be received from a friend, the mere act of telling about a trouble will relieve it somewhat.

Another essential of psychological hygiene is *social participation*. Maladjustments and persistent nonadjustive reactions thrive on solitude. When an individual is engaged in really cooperative activity with others—in work, in study, in athletics, in recreation, or simply in conversation—he cannot think so much about his own troubles. He must be alert to the actions of the others and consequently he becomes more objective in his consideration of himself. A valuable trait that can be exercised in group contacts is *social objectivity*. An individual should cultivate the habit of seeing other people as they are, uncolored by his own egotistical interpretations of their behavior. A maladjusted person will often believe that others are prejudiced against him, when they are really paying him little attention and are occupied entirely with their own interests which happen to conflict with his. An objective attitude toward other persons can comprehend their points of view, and therefore can compromise with them and adjust to them more effectively.

All the principles of positive psychological hygiene can be summarized by one: to utilize *creative thinking* to solve personal problems. The scientist or other creative thinker first gathers all the data about a problem and applies to it the knowledge that has been accumulated in past years. Then he formulates a hypothesis to explain his data, and tests this generalization by further experiments. In a like way, an individual may review the facts of his difficulties objectively, and secure advice about them. Next, he can make a hypothesis

as to what he should do, and test it by putting his purpose into action. The first hypothesis may not be correct, and he may have to try others until eventually he reaches a satisfactory solution. The planned life proposed by this method is far superior to the hit-or-miss procedures by which most people stumble into their social and personal adjustments. In this sense, creative thinking is a way of living that will lead to individual satisfaction and social effectiveness.

SUGGESTED READINGS AND REFERENCES

For each chapter of the text, two forms of bibliographic aids are given. These are the *suggested readings*, and the *references*.

The *suggested readings* for each chapter have been prepared to guide the student to a broader acquaintance with psychology than can be acquired by reading one book. No student will be likely to read all the books suggested, but a moderate investment of time in the library will pay worth-while dividends. He may browse widely in some fields, or study intensively on selected topics that are of special interest. Some references are to semi-popular books that will enlist the student's interest and broaden his knowledge without adding difficulties of study. Other readings are of a more advanced nature than is typical of an introductory course in psychology, but can be read with profit by students of more than average ability or industry. The type of reference is indicated by a brief explanation in connection with each suggested reading.

The *references* give the full citation of every book mentioned in the suggested readings, except for those listed below the general references. In the references also will be found all research studies of which specific mention has been made in the chapter, and a number of other research articles and fundamental books that were used by the authors in writing the chapter, or that are basic contributions to the topic with which the chapter deals. These citations will enable the student or instructor to verify the conclusions reached by the authors.

To prevent a tedious repetition of certain common references, a number of books of very wide usefulness are listed below under the heading of *general references*. These books are cited by an abbreviated form of reference in the suggested readings for many chapters, and are not listed again in the chapter bibliographies. The general reference books will constitute a suitable reserve library shelf for the class in beginning psychology.

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Chapter I

THE AIM AND SCOPE OF PSYCHOLOGY

Suggested Readings

As a preliminary survey of the nature and problems of psychology, the student may browse through the entire text, and examine any other general textbooks in psychology that are available. Robinson, *Readings,* Ch. 1, and Skinner, *Readings,* Chs. 1 and 2, describe the general nature of science, and the problems and methods of psychology.

Frauds and superstitions that are incorrectly attributed to psychology are discussed briefly in Valentine, *Foundations,* Ch. 2. Jastrow, *Fact and fable in psychology;* Swift, *The jungle of the mind;* and Yates, *Psychological racketeers,* are popular but well-documented books on this subject, any one of which will constitute an intensely interesting evening's reading. Achilles, *Psychology at work,* is an easily read survey of the proper applications of scientific psychology.

The experimental methods of psychology are illustrated copiously in Garrett, *Experiments;* Valentine, *Readings* and *Foundations*; and Crafts, *Experiments.* A preliminary survey of these books will give an impression of the general spirit and methods of psychological research. Of the specific research studies cited in the chapter, those on memory, on infants' emotions and on gifted children are expanded in later chapters of the book. On studies of reaction time, see Garrett, *Experiments,* Ch. 9; Valentine, *Readings,* Ch. 1; and Robinson, *Readings,* pp. 495-498 (*rev. ed.,* pp. 625-628).

The history of psychology may interest many students, and brief accounts will be found in Skinner, *Readings,* Ch. 25; and Hulin, *A short history of psychology.* For reference on the meanings of psychological terms, the *glossary* of this book will be useful, as will also English, *A student's dictionary of psychological terms.* The most extensive reference of this sort is Warren, *Dictionary of psychology.*

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Chapter II

THE NATURE OF HUMAN ADJUSTMENTS

Suggested Readings

All psychology is based on the principles of adjustment, stimulus, and response developed in this chapter. For further treatment of fundamental principles see Skinner, *Readings,* Ch. 3. Adjustive behavior in single-

celled animals is described in Jennings, *Behavior of the lower organisms.* Basic physiological adjustments are discussed by Cannon, *The wisdom of the body.* Social and personal adjustments are illustrated copiously in Allport, *Social psychology,* Ch. 14; Shaffer, *The psychology of adjustment;* and Guthrie, *The psychology of human conflict.*

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Chapter III

THE BODILY BASIS OF BEHAVIOR

Suggested Readings

For more extended reference on the structure and function of the nervous system, see Skinner, *Readings,* Chs. 9, 11; Robinson, *Readings,* Chs. 2, 3; and Skinner, *Educational readings,* Ch. 2. Of a more advanced nature, but concise and understandable are Lickley, *The nervous system,* and Herrick, *Introduction to neurology.*

The student who desires extensive but simple readings on the nervous system will find helpful Herrick's two non-technical books, *The thinking machine,* and *Brains of rats and men.* To read these books is a pleasure rather than a task.

On experimental studies of the functioning of the nervous system, the summaries in Garrett, *Experiments,* Ch. 14; and Crafts, *Experiments,* Chs. 11, 12, 13, may be consulted.

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Chapter IV

THE BEGINNINGS OF BEHAVIOR

Suggested Readings

The general principles of maturation are summarized by Coghill in Wheeler, *Readings,* pp. 528-551; and in Coghill, *Anatomy and the*

problem of behavior. A summary of prenatal development may be found in Brooks and Shaffer, *Child psychology,* Ch. 2. Also see Valentine, *Foundations,* Chs. 3, 4; Skinner, *Readings,* Ch. 8; and Skinner, *Educational readings,* Ch. 4.

Experimental studies of infant behavior are described in Valentine, *Readings,* Ch. 3; Garrett, *Readings,* Ch. 7; and Crafts, *Experiments,* Chs. 1, 3.

Several textbooks in child psychology are useful supplementary references. See Goodenough, *Developmental psychology;* Curti, *Child psychology;* Jensen, *Psychology of child behavior;* and Jersild, *Child Psychology.* The most extensive reference is the *Handbook of child psychology.*

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Chapter V

LEARNED BEHAVIOR

Suggested Readings

General principles of learning are discussed in Skinner, *Readings*, Chs. 12, 13; Skinner, *Educational Readings*, Chs. 5, 6, 7, 8; and Valentine, *Foundations*, Ch. 13. A wide variety of experiments in learning will be found in Valentine, *Readings*, pp. 409-467.

References that deal particularly with trial and error learning are Garrett, *Experiments*, Chs. 5, 11; Crafts, *Experiments*, Chs. 10, 17; Wheeler, *Readings*, pp. 81-113; and Woodworth, *Experimental*, Chs.

6, 7. The conditioned reaction is described by Garrett, *Experiments,* Ch. 4; Valentine, *Readings,* Ch. 2; and Woodworth, *Experimental,* Ch. 5. Associative learning in the broader sense is the subject matter of Robinson, *Association theory today*. Learning curves and their applications are described in texts in educational psychology, such as Gates, *Psychology for students of education,* Ch. 9; Jordan, *Educational psychology,* Chs. 3, 5; Skinner, *Educational psychology,* Chs. 12, 14; and Thorndike, *Educational psychology,* Vol. II.

The formation of habits is considered by Robinson, *Readings,* Ch. 5; and Crafts, *Experiments,* Ch. 22. The ethical and practical aspects of habit have never been better discussed than by William James in his *Talks to teachers,* Ch. 8, and in his *Principles of psychology,* Vol. I, Ch. 4. A selection from the latter is quoted in Robinson, *Readings,* pp. 132-138 (rev. ed., pp. 174-180).

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Chapter VI

EMOTIONAL BEHAVIOR

Suggested Readings

The early development of emotion is described in Garrett, *Experiments,* Ch. 10; and Valentine, *Foundations,* Ch. 9. General references on the entire subject of emotion include Robinson, *Readings,* Ch. 18; Skinner, *Readings,* Ch. 16; and Skinner, *Educational readings,* Ch. 9. Experimental studies are summarized in Wheeler, *Readings,* pp. 199-224; Crafts, *Experiments,* Chs. 6, 7; Valentine, *Foundations,* Ch. 10; and Valentine, *Readings,* Ch. 5, and pp. 571-587.

More extensive references on emotion are Woodworth, *Experimental,* Chs. 11, 12, 13; Bard and Landis, in *Handbook of general experimental psychology,* Chs. 6, 7; and Jones in *Handbook of child psychology,* second ed., Ch. 6.

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Chapter VII

MOTIVATED AND VOLUNTARY BEHAVIOR

Suggested Readings

A more extended treatment of the topic of motivation is given by Young, *Motivation of behavior;* Murphy, *Experimental social psychology*, Ch. 3; Shaffer, *The psychology of adjustment*, Ch. 4; and Guthrie, *The psychology of Human conflict*, Chs. 8, 9, 10. For studies of animal

motivation, see Warden, *Animal motivation*. Other general references are Skinner, *Readings,* Ch. 15; Valentine, *Readings,* Ch. 4; Valentine, *Foundations,* Ch. 6; Crafts, *Experiments,* Ch. 4; and Wheeler, *Readings,* pp. 225-252.

Ideomotor action is treated from an older point of view by Robinson, *Readings,* Ch. 19. Menzies' experiments are reproduced in detail in Crafts, *Experiments,* Ch. 18.

Voluntary action in general is the subject of Skinner, *Readings,* Ch. 21. On hypnosis and allied topics, see Hull, *Hypnosis and suggestibility;* also Wheeler, *Readings,* pp. 49-61; Valentine, *Readings,* pp. 292-309; and Valentine, *Foundations,* Ch. 8.

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Chapter VIII

THE GENERAL NATURE OF EXPERIENCE

Suggested Readings

A survey of the more general facts about sensation and perception is given in Robinson, *Readings,* Chs. 6, 11; Wheeler, *Readings,* pp. 389-410; and in parts of Skinner, *Readings,* Chs. 17, 18. A thorough treatise on experience that is not too hard to read is Boring, *The physical dimensions of consciousness.*

Psychophysics, an inherently difficult topic, is made quite clear by Garrett, *Experiments,* Ch. 12. Technical details are not spared by Woodworth, *Experimental,* Chs. 17, 18; or by Titchener, *Experimental psychology,* Vol. 2. For application of psychophysical concepts to practical tests of muscular, sensory, and perceptual abilities, see Whipple, *Manual of mental and physical tests;* and Garrett and Schneck, *Psychological tests, methods, and results,* Chs. 1, 2, 3.

On language and concepts, see Allport, *Social psychology,* Ch. 8; Gates, *Psychology for students of education,* Ch. 11; Ogden and Richards, *The meaning of meaning;* and Valentine, *Readings,* Ch. 10, and pp. 468-472, 520-531. Crafts, *Experiments,* Ch. 23, gives a full account of the experiment of Carmichael, Hogan and Walter that is summarized in the text.

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Chapter IX

VISUAL EXPERIENCE

Suggested Readings

Visual sensations are described in Robinson, *Readings,* Ch. 7; and Valentine, *Readings,* pp. 355-379. Wheeler, *Readings,* pp. 434-469, is on the blind spot, and Crafts, *Experiments,* Ch. 9, on the duplex theory of retinal action. More advanced treatments of these topics include Woodworth, *Experimental,* Chs. 22, 24; Trowland's Ch. 13, Hecht's Ch. 14, and Graham's Ch. 15 in the *Handbook of general experimental psychology.* On color vision and color blindness, see especially Collins, *Colour-blindness,* and Ladd-Franklin, *Colour and colour theories.*

Principles of perceptions are developed in Köhler, *Gestalt psychology,* especially Chs. 5, 6; and Robinson, *Readings,* Ch. 11. On the perception of distance, depth, and movement, see Carr, *Introduction to space perception;* Garrett, *Experiments,* Ch. 13; Woodworth, *Experimental,* Ch. 26; and Wheeler, *Readings,* pp. 411-433. Stratton's experiment is given rather fully by Valentine, *Foundations,* pp. 217-223.

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Chapter X

AUDITORY EXPERIENCE

Suggested Readings

Simpler references on hearing include Robinson, *Readings,* Ch. 8; and Valentine, *Readings,* pp. 314-354. Much of the most significant recent research and writing on hearing has been done by physicists and communication engineers. Students of psychology may profit from reading parts of books such as Watson, *Sound;* Jones, *Sound;* and Fletcher, *Speech and hearing.* Among the more advanced descriptions by psychologists are Stevens and Davis, *Hearing;* Woodworth, *Experimental,* Ch. 21; and Chs. 16, 17, 18 by Banister, Hartridge, and Davis, in the *Handbook of general experimental psychology.*

The psychology of music is well represented by an old but excellent reference: Gurney, *The power of sound.* A recent summary is Seashore, *Psychology of music.* Auditory space is discussed by Carr, *Introduction to space perception,* Chs. 4, 5.

References

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Chapter XI

OTHER MODES OF EXPERIENCE

Suggested Readings

Robinson, *Readings,* Ch. 9, covers taste, smell, and the somesthetic senses. Rather thorough treatments of these topics may be found in Woodworth, *Experimental,* Chs. 19, 20. The ultimate available reference is Ch. 19 by Crozier, Ch. 20 by Nafe, Ch. 4 by Dusser de Barenne, and Ch. 5 by Cannon, in the *Handbook of general experimental psychology.* Clear and elementary descriptions of experiments on selected topics of cutaneous sensitivity are given by Wheeler, *Readings,* pp. 484-516; and Valentine, *Readings,* pp. 380-405.

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Chapter XII

REMEMBERING

Suggested Readings

The entire memory process is described in Robinson, *Readings,* Ch. 13; and Skinner, *Readings,* Ch. 14. Experiments on this topic may be found in Garrett, *Experiments,* Chs. 3, 6; Valentine, *Readings,* pp. 473-483; Valentine, *Foundations,* Ch. 14; and Crafts, *Experiments,* Chs. 19, 20, 21. On imagery and association, see Robinson, *Readings,* Ch. 12. Woodworth, *Experimental,* Chs. 2, 3, 4, gives an especially clear, although detailed, account of experiments in memory.

The effect of pleasantness and unpleasantness on retention, and the results of repression on adjustments are described in Shaffer, *The psychology of adjustment,* Ch. 8. Mental discipline and transfer of training are treated at more length in Jordan, *Educational psychology,* Chs. 7, 8.

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Chapter XIII

THINKING

Suggested Readings

Some significant experiments on problem-solving are cited by Valentine, *Readings*, pp. 212-240, 503-519. Another reference on problem-solving is Skinner, *Educational readings*, Ch. 13.

Dewey, *How we think*, should be read by all who have a special interest in the reasoning process. Secondary references include Robinson, *Readings*, Ch. 16; Skinner, *Readings*, Ch. 20; Valentine, *Foundations*, Chs. 15, 16; and Crafts, *Experiments*, Ch. 24. Experiments on the motor

interpretation of consciousness, including those of Jacobson and Max, are given in Crafts, *Experiments,* Ch. 26. Other experiments are described in Wheeler, *Readings,* pp. 23-48, 114-145. Experiments on problem-solving are given in Ch. 29, and introspective studies on thinking in Ch. 30, of Woodworth, *Experimental.*

On creative imagination, see Skinner, *Readings,* Ch. 19; and Skinner, *Educational readings,* Ch. 12. Applications to creative processes in the arts are made by Schoen, *Art and beauty.* Other worth-while books on imagination are Wallas, *The art of thought;* Downey, *Creative imagination;* and Spearman, *Creative mind.*

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Chapter XIV

ABILITIES AND THEIR MEASUREMENT

Suggested Readings

The history and early development of mental tests are described by Peterson, *Early conceptions and tests of intelligence*. For the most recent revision of the Binet tests, see Terman and Merrill, *Measuring intelligence;* and for performance tests see Bronner, *et al., A manual of individual mental tests and testing*. Freeman, *Mental tests,* is a general survey of the field.

Excellent summaries of the results of the applications of tests to various groups are Anastasi, *Differential psychology,* and Schwesinger, *Heredity and environment*.

There are many brief selections on tests and test findings in the general references, including: Robinson, *Readings,* Ch. 21; Skinner, *Readings,* Chs. 4, 5, 7; Skinner, *Educational readings,* Chs. 17, 18; Wheeler, *Readings,* pp. 65-80; Garrett, *Experiments,* Chs. 1, 2, 8; Valentine, *Readings,* pp. 555-570; Valentine, *Foundations,* Chs. 17, 18, 19; and Crafts, *Experiments,* Chs. 15, 16, 27, 28.

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Chapter XV

PERSONALITY AND CHARACTER

Suggested Readings

On the traits of personality and their measurement, see Symonds, *Diagnosing personality and conduct.* Allport, *Personality* is a comprehensive discussion of the nature, development, structure and analysis of

personality. General references are Robinson, *Readings,* Ch. 20; Skinner, *Readings,* Ch. 6; and Skinner, *Educational readings,* Chs. 11, 22.

The standard work on the measurement of interests is Freyer, *The measurement of interests.* The nature and formation of attitudes are described in Allport's Ch. 17 of the *Handbook of social psychology.* On some other measurements in social psychology see Valentine, *Readings,* pp. 588-599; and Valentine, *Foundations,* Ch. 7.

Methods and results of the investigations carried out by the Character Education Inquiry are given in the three volumes by Hartshorne and May, listed below. Interesting studies and proposals concerning character education are described by Jones, *Character and citizenship training in the public school.*

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Chapter XVI

SOCIAL ADJUSTMENTS

Suggested Readings

Social adjustments and maladjustments are described by Bagby, *The psychology of personality,* an interesting little book that can be read in an evening. More extended references are Shaffer, *The psychology of adjustment;* Guthrie, *The psychology of human conflict;* and Louttit, *Clinical psychology*. Brief readings include Skinner, *Readings,* Ch. 22; Skinner, *Educational readings,* Ch. 23; and Valentine, *Foundations,* Ch. 11.

Adjustments in business and industry are treated by Fisher and Hanna, *The dissatisfied worker;* and Anderson, *Psychiatry in industry*. Teachers and prospective teachers will find Symonds, *Mental hygiene of the school child,* valuable.

The serious mental disorders are described briefly in Hart, *The psychology of insanity,* and by Shaffer's Chs. 9, 10, 11, in *Fields of psychology*. Textbooks in abnormal psychology may be consulted for more details, such as Dorcus and Shaffer, *Textbook of abnormal psychology,* and Fisher, *Introduction to abnormal psychology*. On experimentally

induced neurotic behavior in animals, see Maier, *Studies of abnormal behavior in the rat.*

For positive psychological hygiene, see Morgan, *Keeping a sound mind,* a book intended for the self-guidance of college students. On how to get along with people, a useful book is White, *The psychology of dealing with people.*

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